Accuracy of predicting genetic merit of A.I. sampled bulls from pedigree information and the impact of son's proof on dam's PTA.

by

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(ABSTRACT)

A total of 1,644 A.I. sampled bulls born from 1984 to 1986 with first proofs from Winter 90 to Summer 91 were used to determine the accuracy of predicting DYD and PTA from different sources of pedigree information obtained before the bull had daughter information. Traits evaluated were milk, fat and protein. Pedigree sources considered were PA, PI, PTA_{SIRE} and PTA_{DAM}. Approximate weighted regression was used to determine which pedigree source predicted DYD or PTA with the highest accuracy (highest R^2). For all traits, PA had a higher R^2 for DYD and PTA than PI. Regression coefficients were less than one for PA and PI. R^2 values for PA to predict first DYD milk, fat and protein were .17, .20 and .18, respectively. R^2 for PA to predict first PTA milk, fat and protein were .47, .54 and .49, respectively. Adding PTA_{DAM} to the model with PTA_{SIRE} resulted in a higher R^2 than the model with PTA_{SIRE} alone. As expected R^2 values were similar for PA and the model with PTA_{SIRE} and PTA_{DAM}. However, the weights for PTA_{SIRE} and PTA_{DAM} were less than .5. Higher weights and R^2s for predicting PTA compared to predicting DYD resulted from the part-whole relationship between bull's PTA and his PA. Overall, weights and R^2 were less than expected, but reasonable accuracy was obtained in estimating a young bull's DYD and PTA from pedigree estimates. Accuracy of prediction varied depending on when the bull received his first proof. R^2 values of different groups of bulls based on the date of first DYD and PTA ranged from .06 to .20, .08 to .15 and .05 to .12 for predicting first DYD from PA for milk, fat and protein, respectively. Prediction accuracy in some groups of bulls was less possibly because of the limited number of sires and reduced variation in sire PTAs. Changes in evaluation proce-

dures to expand the variance of extended records and to account for differences in within herd variance may have adversely affected the accuracy of prediction.

The impact of the addition of granddaughters (son's daughters) on the PTA of the dam was evaluated. Addition of granddaughter information decreased the average of dam's PTA 70 kg, indicating the dams' PTAs were generally inflated. Granddaughter information measured relative to PA of the son was useful to predict the change in the dam's PTA at the AM evaluation the dam's sons received first proofs. Regression coefficients ranged from .30 to .39, which were similar to the weights for w_3 in the PTA function. R^2 for the regressions ranged from .33 to .72. Predicting further change in dam's PTA (after the AM evaluation first granddaughter information was received) resulted in lower R^2 (.13 to .35) for additional granddaughter information.

Evidence of bias and/or errors were found in bulls sampled outside the respective A.I. organizations' designated sampling herds. These bulls had PAs that overestimated their DYDs for milk, fat and protein by 107 kg, 7.5 kg and 5.7 kg, respectively. The PAs of these bulls overestimated the PTAs by 97 kg, 6.8 kg and 4.5 kg for milk, fat and protein, respectively. Discrepancies were also found between avarage PTAs and DYDs and the PAs of bulls based on the rank of the dam's PTA. Bulls from dams with lower PTAs tended to have PAs that underestimated their DYDs by 48 kg and .5 kg for milk and fat, respectively. These bulls had PAs that underestimated their PTAs for milk, fat and protein by 42 kg, .5 kg and .6 kg, respectively. Examination of bulls from high ranking dams for PTA milk, fat or protein revealed that bulls from dams with higher PTAs tended to have PAs that overestimated their DYDs by 65 kg, 5.3 kg and 4.5 kg for milk, fat and protein, respectively. The PAs of these bulls overestimated their PTAs by 49 kg, 4.2 kg and 2.9 kg, for milk, fat and protein, respectively.

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Table of Contents

List of Tables

Introduction

When a young bull is selected for progeny testing in the A.I. industry the only information available to estimate his genetic merit is pedigree information. Theoretically, various sources of pedigree information should provide accurate prediction of young bulls' genetic merit. Because selecting the young bulls for progeny testing can account for 70 to 76 percent of the total genetic gain possible in the dairy cattle population (Robertson and Rendel, 1950; Skjervold, 1963; and Van Vleck, 1976), it is important that the evaluations of the parents be accurate to provide a good estimation of young bulls' genetic merit.

Past research has revealed accurate prediction of bulls' future genetic merit from estimates of daughter performance is possible from various sources of ancestor information. Regression coefficients and R^2 are less than the expectations for all previous genetic evaluation procedures. Pedigree Index (PI), $.5(PD_{sire}) + .25(PD_{MGS})$, used in the Modified Contemporary Comparison (MCC) genetic evaluation accounts for the parent contribution to the individual by its inclusion in the calculation of ancestor merit (AM). $AM = \alpha_i + PI$ where α_i varies with year of birth and sampling method (A.I. or non-A.I.). Ancestor merit is then included with modified contemporary deviation ($\overline{MCD}$) to calculate bull's predicted difference (PD) as $PD = R(\overline{MCD}) + (1 - R)AM$.

The current animal model evaluation uses parent average (PA), which is $.5(PTA_{sire}) + .5(PTA_{dam})$, to account for the ancestor contribution to the predicted transmitting ability (PTA) of the individual. PTA is calculated similarly for cows and bulls and can include parent, individual, and progeny contribution. The formula is $PTA = w_1(PA) + w_2(YD/2) + w_3(\overline{2PTA_{prog} - PTA_{mate}})$, where w_1,w_2, and w_3 are weights which sum to one and w_2 is zero for bulls. Solutions are obtained by iteration and all known relatives influence an animal's PTA. Therefore, not only does the PA affect the PTA of the young bull, but the PTA of the young bull affects the PA. This results in a part-whole relationship between a bull's PTA and his PA. Thus, the PTA_{prog} is influenced by the PA of the sire.

A daughter yield deviation (DYD) can be calculated from the YD of the daughters accounting for the PTA_{mate}. The formula is $DYD = \sum q_{prog} w_{2prog}(YD_{prog} - PTA_{mate}) / \sum q_{prog} w_{2prog}$. The resulting DYD is much less interrelated to the PA than the PTA. Therefore, predicting the DYD of a young bull from ancestor information prior to the young bull having daughters, removes the part-whole relationship between young bull and parents that is present with the PTA. The DYD can be used with PA to calculate the PTA of a bull using the following formula. $PTA = x_1PA + x_2DYD$, where x_1 and x_2 are weights which sum to one. As a bull receives more daughter information and his reliability approaches one, more weight is given to the DYD and it virtually becomes the PTA. Using the DYD as the estimate of the bull's progeny performance gives a better estimate of the true pedictive value of ancestor information than using the PTA.

The objectives of this study were:

1. To determine the accuracy of predicting a young progeny test bull's genetic merit from four different sources of pedigree information.

2. To determine the effect of daughter information of progeny test bulls (granddaughter information) on dam's PTA.

3. To determine if there is evidence of bias in bull dam evaluations and if it is more prevalent for some bull dam groups than others.

Review of Literature

Selecting the parents of young bulls to enter A.I. progeny testing programs can theoretically account for 70 to 76 percent of the total genetic gain possible in the dairy cattle population (Robertson and Rendel, 1950; Skjervold, 1963; Van Vleck, 1976). Young bulls selected for progeny testing by A.I. organizations are selected based on their pedigree. The theoretical upper limit of the correlation between the estimate of young sires'genetic merit and actual merit is $\sqrt{.5}$ or .71. According to Henderson (1964) the practical upper limit of .67 can be obtained if the sire has many progeny and the following information on the dam is available:

1. five records
2. many paternal sisters
3. five daughters with two records each
4. four maternal sisters
5. five records on her dam
6. many paternal sisters of her dam

This extensive amount of information is available for few cows. Therefore, the published accuracy of pedigree information is seldom as high as .67.

Selecting bull dams based on different parities

Molinuevo and Lush (1964) reported that using first lactation records on daughters provided accurate information about the breeding value of the bull as opposed to waiting for second or third lactation records. Butcher and Legates (1976) found a higher correlation between son's predicted difference (PD) and dam's first lactation than second, third, fourth, or fifth lactations. When Vinson and White (1982) used only dams' lactations initiated prior to the birth of young bulls to be progeny tested they found estimated transmitting ability (ETA) from dam's first lactation only was a better predictor of the young bulls performance than dam's ETA from later lactation (besides first) and all lactations. Murphy et. al. (1982) found dam's ETA based on first lactation a better predictor (.33 vs. .12) of son's transmitting ability than dam's ETA calculated from all lactations under the Northeast Artificial Insemination Sire Comparison (NEAISC). The high correlations from first lactations may have been influenced by the young bull proofs being based solely on first lactation daughters. However, based on these findings dam's ETA from first lactation could be used to predict young bulls' genetic merit with reasonable accuracy in the parent average (PA). The PA, which is .5(sire's transmitting ability) + .5(dam's transmitting ability), would account for more of the genetic relationship between parents and young bulls than PI. Using dam's first lactation may also lessen the probability of dams treated preferentially from becoming bull dams.

Theoretical weights to predict transmitting ability

According to Van Vleck (1982), the theoretical weights for sire and dam genetic evaluations to predict young bulls' estimated transmitting abilities are equal when the evaluation of the sire is only from his daughters and the dam evaluation is only from her records. The theoretical weights for sire and dam are both .5 to precict progeny. However, because of limited information, the weights are usually less than .5 for sire and dam when the son receives his initial proof based on first crop daughters, but may be equal. Including maternal grand sire (MGS) in the evaluation of the dam changed the theoretical weight of regressing son on dam very little. Because MGS is included in the evaluation of the dam, the theoretical weight for MGS is zero when young bull's estimated transmitting ability is regressed on sire's, dam's, and MGS's transmitting abilities. The expected values for PA and PI to predict the true transmitting ability of a young bull are both 1.

Selecting young bulls based on pedigree

Many studies have dealt with the ability of pedigree information to predict the genetic merit of young bulls in progeny test programs. Tables 1 and 2 show the resulting regression coefficients and R^2 values for these studies.

Predicted Difference (PD) was an estimate of a bull's transmitting ability and prior to 1974 was based only on daughter information. Before 1974, PD was calculated by the following:

$$PD = R(HC)$$

where:

R = Repeatability

HC = $(\overline{\text{Daughter}} - \text{AHA})$

AHA = Adjusted Herd Average

Vinson and Freeman (1972) regressed PD's of young bulls on pedigree estimates computed from sire information alone, dam information alone, and the two sources together as a midparent estimate. For milk yield, the regression coefficients were .40, .43, and .43 for young bull regressed on sire, dam, and midparent, respectively. The correlations between young bull and sire, dam, and midparent were, respectively .20, .11, and .22. For fat yield the regression coefficients were .41, .39, and .34; correlations were .19, .11, and .17 for sire, dam, midparent, respectively.

Table 1. Coefficients, R^2 and expected values in ( ) for regressions of bull's genetic merit for milk on Sire, Dam, PA or PI.

Trait of bull predicted	Sire	Dam	PA	PI	R^2	Source
PD[a]	.40(.47)				.04	Vinson & Freeman (1972)
PD[a]		.43(.30)			.01	Vinson & Freeman (1972)
PD[a]			.43		.05	Vinson & Freeman (1972)
HC[a]	.44				.12	Stewart et al. (1976)
HC[a]				.94	.16	Stewart et al. (1976)
BV[b]	.40				.18(.14)	Butcher & Legates (1976)
BV[b]		.37			.04(.04)	Butcher & Legates (1976)
PD[b]				.85(1.0)	.29(.37)	Powell et al. (1977)
MCD[b]				.84(1.0)	.16(.20)	Powell et al. (1977)
PD[b]				.69	.10	McCraw et al. (1980)
PD[c]	.49(.50)				.32	Schaeffer (1981)
PD[c]		.34(.50)			.21	Schaeffer (1981)
PD[b]	.32(.50)				.10	Vinson & White (1982)
MCD[b]	.44(.50)				.08	Vinson & White (1982)
PD[b]	.42				.27	Lee (1983)
PD[b]			.71		.30	Lee (1983)
PD[b]				.81	.31	Lee (1983)
PD[b]				.77	.08	Funk & Hansen (1988)
MCD[b]				.74	.05	Funk & Hansen (1988)
PTA[d]				.90	.47	Ferris (1990)
DYD[d]				.88	.41	Ferris (1990)
PTA[d]			1.08		.64	Ferris (1990)
DYD[d]			1.08		.56	Ferris (1990)

[a]Herdmate Comparison
[b]Modified Contemporary Comparison
[c]Canadian BCAs
[d]Animal Model

Table 2. Coefficients and R^2 of regressions of bull's genetic merit for milk on Sire, Dam and MGS.

Trait of bull predicted	Sire[d]	Dam[d]	MGS[e]	R^2	Source
PD[a]	.48	.24	.17	.32	Schaeffer (1981)
PD[a]	.46	.31		.35	Schaeffer (1981)
PD[a]	.50		.24	.29	Schaeffer (1981)
PD[b]	.37	.19	.14	.26	Rothschild et al. (1981)[f]
PD[b]	.40	.31		.25	Rothschild et al. (1981)
PD[b]	.31		.17	.14	Vinson & White (1982)
MCD[b]	.44		.23	.11	Vinson & White (1982)
PD[b]	.29	.16		.08	Vinson & White (1982)
MCD[b]	.46	.23		.08	Vinson & White (1982)
PD[b]	.29	.11	.19	.13	Vinson & White (1982)
MCD[b]	.46	.15	.27	.12	Vinson & White (1982)
PD[b]	.42	.27		.31	Lee (1983)[f]
PD[b]	.40		.21	.31	Lee (1983)
PD[b]	.41	.19	.13	.32	Lee (1983)
DYD[c]	.50	.46		.50	VanRaden et al. (1989)
PTA[c]	.50	.46		.61	VanRaden et al. (1989)

[a]Canadian BCAs
[b]Modified Contemporary Comparison
[c]Animal Model
[d]Expected value of both Sire and Dam was .50
[e]Expected value of MGS was 0 when included with Sire and Dam and .25 when included with Sire.
[f]No expectations given.

Stewart et. al. (1976) regressed herdmate comparison (HC) genetic evaluations of Canadian progeny tested bulls on various estimates of pedigree information, which were sire, PI, and an index developed by Freeman and Burnside (1972). The index was $.5(HC_{sire}) + .47(ETA_{dam}) + .16(ETA_{MGD})$. The regression of HC on the index was .70 ($R^2 = .17$), on the sire .44 ($R^2 = .12$), and on the PI .94 ($R^2 = .16$). PI was judged the best source of pedigree information to predict young bulls' HC.

Another study on predicting progeny performance of Canadian A.I. progeny test bulls from pedigree information was done by Schaeffer (1981). The regression of 358 young bull PDs on an index containing sire, dam, and both maternal grandparents yielded respective coefficients of .44, .26, .12, and -.097 for sire, dam, MGS, and maternal granddam (MGD). The correlation of this index with young bull's PD was .52. Removing MGD from the model resulted in a data set containing 456 young bulls. The correlation increased to .57. The resulting regression coefficients were .48, .24, and .17 for sire, dam, and MGS, respectively. The regression of young bull's PD on sire's proof and dam's ETA yielded the partial regression coefficients of .46 for sire and .31 for dam. The partial regression of young bull PD on sire and MGS resulted in coefficients of .50 and .24 for sire and MGS, respectively. The correlations between young bull PD and the two pedigree indexes were .59 and .54 for the index containing sire's proof and dam's ETA and the index containing sire's and MGS's proof, respectively. Regression of young bull's PD on sire's evaluation alone gave near expected results with a coefficient of .49. This was also the case for MGS (.25). However, the regression of young bull's PD on dam's ETA alone gave less than expected results with a coefficient of .34.

Butcher and Legates (1976) regressed the breeding value (BV) of young bulls on a pedigree index (Ped Idx) which was based on dam's first three lactations, sire's proof based on first lactation daughters, and MGS's proof from first lactation daughters. The regression coefiecient was .69 for Ped Idx to predict young bull's BV, while the correlation between the estimates was .47. The correlations between son and sire and son and MGS were .43 and .24, respectively. Correlations between son and dam's BV based on lactation one, two, three, four, five, one and two, one, two and three, or all available lactations were: .21, .16, .16, .08, .08, .21, .22, and .15.

Powell et. al. (1977) examined the relationship of young bulls' modified contemporary deviation ($\overline{MCD}$) with PI. The correlation between $\overline{MCD}$ and PI was .40, while the correlation between PD and PI was .54. The regression coefficient of $\overline{MCD}$ on PI was .84, while the regression coefficient for PD on PI was .85. Using $\overline{MCD}$ instead of PD removes the part-whole relationship between PD and PI. PI was used in the PD formula to group bulls into genetic groups based on the merit of their pedigrees. The genetic group average (GA) was then used in calculating the PD.

$$PD = R(\overline{MCD}) + (1 - R)GA$$

where:

R = repeatability

$\overline{MCD}$ = average modified contemporary deviation of the bull's daughters

GA = average $\overline{MCD}$ of bulls in the same PI group

GA was used instead of PI directly in the PD calculation because it was not known if there was a linear relationship between PI and daughter $\overline{MCD}$.

In July, 1983 USDA replaced GA with ancestor merit (AM). PD was then calculated as:

$$PD = R(\overline{MCD}) + (1 - R)AM$$

where:

AM = α_i + bull's PI

PI = $.5(PD_{sire}) + .25(PD_{MGS})$

The α_i used to calculate AM is the average of the difference between $\overline{MCD}$ and PI weighted by repeatability. Bulls were categorized by breed, birth year and method of sampling. A different α was used for each group (Norman, 1986).

McCraw et. al. (1980) predicted young bulls' PD from three composite pedigree index models: sire, dam and MGS, and sire and MGS. The first two pedigree index models used PDs and ETAs from 1971. This was an estimate of the pedigree near the birth of the young bulls when they would have been selected for progeny test. The third pedigree index model consisted of sire and MGS PD from 1976 when the young bulls' PD was estimated for the regressions on the index models. By this time the repeatability of PDs for sire and MGS would be higher (near 1.0) and the PDs would be a more accurate estimate of the true transmitting abilities. Milk yield regression coefficients were .76, .69, and .79; while fat yield regression coefficients were .54, .55, and .64 for the respective index models.

Rothschild et. al. (1981) predicted young bulls' PD and $\overline{\text{MCD}}$ from PDs and $\overline{\text{MCD}}$s for male relatives and $\overline{\text{MCD}}$s and Cow Indexes (CI) for female relatives using stepwise regression. The resulting models found sire, MGS, and dam important in predicting young bulls' PD and $\overline{\text{MCD}}$ for milk and fat yield. Predicting fat percent resulted in sire and dam being important. MGS was more important than dam for predicting milk and fat yield, but dam was more important than MGS for predicting fat percent.

Vinson and White (1982) used the genetic evaluations of sire and MGS just before the birth of the young bull to predict PD. Genetic evaluations of dams were from first lactation only, the average of later lactations, and all lactations. Only records initiated prior to the birth of each son were used. The regression of son's PD on sire's PD yielded a coefficient of .32 and an R^2 of .10. Regressing son's PD on sire and MGS's PD resulted in coefficients of .31 for sire and .17 for MGS with an R^2 of .14. Regressing son's contemporary deviation ($\overline{\text{MCD}}$) on sire's and MGS's PD independently gave coefficients of .44 and .23, respectively with an R^2 of .11. Regression of son's $\overline{\text{MCD}}$ on sire's PD alone gave a weight of .44 and an R^2 of .08. The latter two regressions removed the part-whole relationship of son's PD with sire and MGS PD. Regressing son's contemporary deviation on sire, dam, and MGS gave coefficients of .46, .15, and .27 for sire, dam, and MGS, respectively. It was speculated that the higher weights for the PD of ancestors' when predicting $\overline{\text{MCD}}$ vs. PD of the son was due to the reduced variation of PD compared to $\overline{\text{MCD}}$ (Vinson, personal communication). The regression of son PD on dam's ETA from first lactations resulted in a better predictor than dam's ETA from later lactations or from all lactations suggesting preferential treatment of dams after they perform well in first lactation. Regression coefficients and R^2 in parentheses were .16(.01), .10(.01) and .09(.02) for first lactation, later lactation, and all lactations, respectively.

Lee (1983) predicted young progeny test bulls' PD from various combinations of ancestor ETAs. Birth year of the young bull was used as a covariate in each model. The regression coefficient for sire's PD was .42. The partial regression coefficients when young bulls' PD was regressed on sire and dam; sire and MGS; or sire, dam and MGS were .42 and .28; .40 and .21; and .41, .19, and .13, respectively. The coefficient of MGS in the model including sire, dam and MGS was expected to be zero because MGS PD was accounted for in the dam's ETA. When young bulls' PDs were regressed on indexes consisting of ancestor information (PA and PI) the coefficients were .71 and .81 for PA and PI, respectively.

Funk and Hansen (1988) measured the ability of the PI of a young bull from two, three, and four generations to predict the PD and $\overline{MCD}$ of young progeny test bulls. PI was $.5(PD_{sire}) + .25(PD_{MGS})$; $.5(PD_{sire}) + .25(PD_{MGS}) + .125(PD_{MGGS})$; or $.5(PD_{sire}) + .25(PD_{MGS}) + .125(PD_{MGGS}) + .0625(PD_{MGGGS})$ for two, three, or four generations, respectively. Regressions coefficients and R^2 in parentheses for PI from two generations were .77(.08) for PD milk yield and .74(.05) for predicting $\overline{MCD}$ milk yield. For fat yield the weights and R^2 in parentheses were .78(.15) for predicting PD and .72(.08) for predicting $\overline{MCD}$ from two generation PI. Using the three generation PI provided slightly more accuracy in predicting young bulls' PD and $\overline{MCD}$ for milk and fat yield. The regression coefficients and R^2 in parentheses for milk yield were .80(.11) and .80(.06) for PD and $\overline{MCD}$, respectively. The regression coefficients and R^2 in parentheses for fat yield were .80(.16) and .74(.09) for PD and $\overline{MCD}$, respectively. PI based on four generations provided no further accuracy in predicting young bulls' PD or $\overline{MCD}$ for milk or fat yield. The weights and R^2 in parentheses for PD and $\overline{MCD}$ milk were .79(.11) and .80(.07), respectively. The weights and R^2 in parentheses for PD and $\overline{MCD}$ fat were .72(.13) and .65(.06), respectively.

In July, 1989 USDA changed the genetic evaluation procedure from the Modified Contemporary Comparison (MCC) to Best Linear Unbiased Prediction (BLUP) under an animal model (Wiggans and VanRaden, 1989). In the animal model, information from all relatives is used through the process of iteration to calculate predicted transmitting abilities (PTA) of bulls and cows. PA replaces PI in the animal model to account for the ancestor contribution. Theoretically the animal model is expected to provide a more accurate predictor of genetic merit because of the inclusion of information from all relatives.

The following formula is used to explain PTA for the animal model:

$$PTA = w_1 PA + w_2(YD/2) + w_3\overline{(2PTA_{prog} - PTA_{mate})}$$

where:

$PA = .5(PTA_{sire}) + .5(PTA_{dam})$

YD = average yield deviation of animal evaluated from management group mates adjusted for management, permanent environment, and sire by herd interaction

PTA_{prog} = the PTA of a progeny of the animal evaluated

PTA_{mate} = the PTA of the other parent of the progeny

The term PTA is used for both cows and bulls. For bulls, w_2 is zero because they have no YD. The weights, w_1,w_2 and w_3, sum to one in such a way that as an animal has more progeny and/or individual records less emphasis is placed on the PA, while more is placed on the progeny and individual production. YD of progeny enters PTA through $\overline{2PTA_{prog} - PTA_{mate}}$. The PTA of the mate is subtracted to account for the genetic merit of the other parent. This is done to prevent bias from mating bulls with the highest (lowest) genetic merit mostly to cows with the highest (lowest) genetic merit.

The PTA of the animal influences the progeny PTA and vice versa. Therefore, $\overline{2PTA_{prog} - PTA_{mate}}$ is not an independent measure of progeny performance. Additionally, not only does the PA affect the offspring, but the offspring's PTA also affects the PA. A more independent measure of progeny performance is daughter yield deviation (DYD) (VanRaden and Wiggans, 1991).

$$DYD = \frac{\Sigma q_{prog} w_{2prog} (YD_{prog} - PTA_{mate})}{\Sigma q_{prog} w_{2prog}}$$

q_{prog} equals one if mate is known
and 2/3 if mate is unknown.

Because bulls have no YD of their own the equation can be rewritten as $PTA_{bull} = x_1 PA + x_3 DYD$, where x_1 and x_3 are weights which sum to one. As the bull receives more progeny the pedigree is weighted less and the DYD more. When the PTA approaches a reliability of one the DYD is virtually the PTA. A more detailed description of the DYD is contained in the Appendix.

As a result of using information on all relatives and the theoretically more optimum PA to account for the ancestor contribution, animal model evaluations of parents should be better predictors of young bulls' genetic merit than the previous MCC evaluations.

VanRaden et al. (1989) computed animal model and MCC evaluations on parents along with animal model evaluations, YD, DYD, MCC evaluations, and $\overline{MCD}$ of progeny. Breeds in the data were Ayrshire, Brown Swiss, Guernsey, and Jersey. Evaluations of parents were from 1982 and included sire, dam, and PA, while evaluations on progeny (sons and daughters) were from 1988.

Correlations were higher for parent evaluations with progeny animal model evaluations than progeny MCC evaluations. Correlations of son's DYD with evaluations on parents were higher or equal for animal model than MCC evaluations, except MCC evaluations for dam and PA were higher than the corresponding animal model evaluations. For Jerseys, the coefficients of regression of progeny on parent evaluations were near the expected value of .5 for animal model and MCC, but animal model evaluations on parents had higher R^2 than MCC evaluations.

A study by Ferris (1990) used July 1989 animal model evaluations to compare the accuracy of PA (sire and dam) and PI (sire and MGS) in predicting MCC evaluations (PD and $\overline{\text{MCD}}$) and animal model evaluations (PTA and DYD) of bulls. The regression coefficients for the MCC evaluations were .63 for PA and .80 for PI to predict PD, while the coefficients were .63 for PA and .71 for PI to predict $\overline{\text{MCD}}$. The regression coefficients for the animal model evaluation were 1.08 for PA and .90 for PI to predict PTA, while the coefficients were 1.08 for PA and .88 for PI to predict DYD. R^2 were higher for predictions under the animal model. The R^2 for PA was .64 for predicting PTA and .56 for predicting DYD. The R^2 for PI was .47 for predicting PTA and .41 for predicting DYD. Under the MCC system the R^2 were similar for PA and PI (.23 vs. .24 for predicting PD. The R^2 were also similar (.15 vs. .14) for predicting $\overline{\text{MCD}}$. Predictions were better for the animal model evaluations. However, this may be partly because the son's evaluation was allowed to influence his ancestor's evaluations, causing a part-whole relationship between son and parents.

Tables 1 and 2 show that the ability of pedigree information to predict transmitting abilities of young progeny test bulls has been well documented. The change to the MCC system in 1974, which included pedigree information along with daughter information (instead of just daughter information), improved the relationship of son with sire and dam. The PI was established as the best predictor of the transmitting ability of a progeny test bull because it provided a reasonably accurate estimate with minimal possibility of bias entering from preferential treatment of the dam. Relationships between pedigree estimates and progeny were less than expected, but provided adequate predictions of the genetic merit of a young progeny test bull. This is expected to continue with the animal model evaluations where PA is used to account for the pedigree contribution. However, because the impact of possible preferential treatment of bull dams is not known and no account is made for the method under which the bull was sampled, relationships may not be as good.

Accuracy of animal model evaluations

In the animal model the measure of accuracy for the PTA is reliability (REL). REL is the squared correlation of an animal's predicted and true transmitting abilities. The term REL is used for both cows and bulls and is based on Daughter equivalents (DE). A DE is the amount of information contributed to a parent by a daughter with one record, many herdmates, and the other parent with a high REL (VanRaden and Wiggans, 1991). The relationship between REL and DE is:

$$REL = \frac{DE}{(DE + 14)}$$

The DE is the sum of DE from PA, the animal's own yield, and the progeny adjusted for mates. The constant 14 was derived from the ratio of error to sire variance after subtracting dam variance from error variance and assuming heritability of .25 for milk yield (VanRaden and Wiggans, 1991).

Before a bull has progeny information the accuracy of the bull's pedigree estimate is the REL of the parent average (REL_{PA}) (VanRaden and Wiggans, 1991).

$$REL_{PA} = .25(REL_{SIRE} + REL_{DAM})$$

Impact of son on dam

In the animal model information on all relatives is used to calculate PTAs. Therefore, just as the parent information affects the young bull, the young bull affects the parent proofs. The concern is how the young bulls' daughters affect the dams' PTA. Although a young bull does influence the sire's PTA, the effect is usually small because most sires of sons have a REL around 99% when their sons receive daughter information. According to VanRaden and Wiggans (1991), Table 3 shows examples of the DE contributed to the dam's REL from her own lactation records and a son's daughter information.

Table 3. Daughter equivalents (DE) contributed to dam's REL from her own lactation records and a son's daughter information[1].

Information available	DE
Dam	
1 lactation record	4.7
3 lactation records	7.8
5 lactation records	9.0
Son	
1 daughter with 1 lactation record	.2
10 daughters in 10 herds, each with 1 lactation record	1.8
50 daughters in 50 herds, each with 1 lactation record	4.4
100 daughters in 100 herds, each with 1 lactation record	5.4
Evaluation with 99% REL and the other parent with 99% REL	7.0

[1]Source (VanRaden and Wiggans, 1991)

Materials and Methods

Source of Data

Pedigree estimates, estimates of transmitting abilities, and accuracies for milk, fat and protein on 1,727 registered Holstein bulls were obtained from the Animal Imrovement Programs Laboratory (AIPL), United States Department of Agriculture (USDA). Source of data was five animal model (AM) sire evaluations from Summer 1989 to Summer 1991. Bulls with birth years from 1984 to 1986 and no official DYD or PTA in Summer 1989 or before were used. The bulls in the data which were progeny tested in herds other than a stud's designated sampling herds and thus, had a large number of first crop daughters were identified as heavily sampled young bulls. These particular bulls were identified by contacting each respective A.I. organization. The 83 bulls of the 1,727 bulls that were identified by their studs as heavily sampled bulls were excluded from all analyses, except for a portion of objective 3. This resulted in 1,644 bulls to be used in the remainder of the study. Young bull, sire, and MGS statistics available were PA, PA_{REL}, REL, PTA, and DYD for milk, fat, and protein.

Data edits

Table 4 contains the list of edits and the number of bulls removed from the data for each edit. Initially, 4,425 bulls with birth years from 1984 to 1986 were available. Removed from the data set were 61 'red' and 6 'red carrier' bulls. Another 1,210 bulls were removed because they already had PTAs (daughter information) in Summer 89. An additional 1,145 bulls were removed because they had not yet been assigned a NAAB stud number equal to 1, 7, 8, 9, 11, 14, 21, 23 or 29 by Summer 89. This left 2003 bulls that fit the initial qualifications. Of the 2,003 bulls, 96 had been designated by their respective A.I. organizations as unique young sires (identified by contacting each respective A.I. organization) and sampled outside of the young sampling herds. Of the remaining 1,907 bulls, 15 were removed because their REL_{PA} decreased from one USDA AM evalution to the next from Summer 89 to Summer 91. Furthermore, 2 non-registered bulls and 5 bulls without PIs were removed. Additionally, 11 bulls were removed because the REL_{DAM} was calculated to be 10% or less at one of the AM evaluations used in the study. Finally, 230 bulls were removed because they had no daughter information (i.e. no DYD) by Summer 91. This left 1,644 bulls eligible for evaluatation in this study. Of the 96 heavily sampled bulls, 2 had decreasing REL_{PA} from one AM evaluation to the next. Also, 11 bulls were removed because they had no daughter information by Summer 91; leaving 83 bulls plus an additional 20 bulls from the 1,644 bulls that had 100 daughters or more in Summer 91 for the evaluations on heavily sampled bulls.

Table 4. Number of bulls removed for each edit from bulls with birth years from 1984 to 1986.

Number removed	Edit
61	red bulls
6	red carrier bulls
1210	bulls with a proof in Summer 89
1145	bulls without an NAAB stud number by Summer 89
96	bulls sampled outside of designated sampling herds
15	bulls with REL of PA that decreased
11	bulls with dam's REL ≤ 10% at any animal model evaluation
5	bulls with missing MGS information
2	grade bulls
230	bulls without a first proof by Summer 91

Calculation of PTA and REL of the dam

Although PTAs and RELs for the dam are not provided on the USDA AM sire summary, they can be calculated within rounding error by using information that is available (VanRaden and Wiggans, 1991). The following formulae were used to calculate the PTA and REL of each dam:

$$PTA_{DAM} = 2(PA_{BULL}) - PTA_{SIRE}$$

$$REL_{DAM} = 4(REL_{PA}) - REL_{SIRE}$$

Calculation of daughter equivalents (DE) and pedigree index (PI)

The REL of a PTA is based on the sum of the DE from all sources of information for the individual. One DE is equivalent to a daughter having one record, an infinite number of management group mates, and the other parent with perfect REL (VanRaden and Wiggans, 1991). For a bull, the total DE in the PTA (DE_{PTA}) are the sum of DE from PA (DE_{PA}) and daughter equivalents from progeny (DE_{PROG}). DE_{PTA} were calculated using the REL of the bull.

$$DE = \frac{14(REL)}{(1 - REL)}$$

Secondly, DE_{PA} was calculated similarly using the REL_{PA}. DE_{PROG} was then calculated as the difference $DE_{PROG} = DE_{PTA} - DE_{PA}$.

A two generation PI was calculated for milk, fat and protein by the following formula:

$$PI = .5(PTA_{SIRE}) + .25(PTA_{MGS})$$

Accuracy of predicting progeny test bulls' genetic merit from different sources of pedigree

The four sources of pedigree information considered were: parent average (PA) = .5(PTA_{sire}) + .5(PTA_{dam}); pedigree index (PI) = .5(PTA_{sire}) + .25(PTA_{MGS}); PTA_{SIRE} and PTA_{DAM}. Pedigree estimates and REL from the July 1989 through the January 1991 USDA sire summaries were used.

To determine the accuracy of predicting progeny test bulls' genetic merit from different sources of pedigree information the following regression models were used:

$$y_i = \alpha + \beta(\text{Pedigree Source}_i) + e_i$$

or

$$y_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + e_i$$

where:

y_i = PTA or DYD for milk, fat, or protein of the i[th] bull weighted by DE_{PROG} or DE_{PTA},

α = y intercept,

β = regression coefficient,

Pedigree Source_i = PA, PI, or PTA_{SIRE}, for the i[th] bull,

x_{1i} = PTA_{SIRE} for the i[th] bull,

x_{2i} = PTA_{DAM} for the i[th] bull,

e_i = error for the i[th] bull with variance proportional to $\frac{1}{DE_{PROG}}$ or $\frac{1}{DE_{PTA}}$.

To account for the heterogeneous error variance of DYD and PTA, coefficients and R^2 from a weighted regression were used to determine the best source of pedigree to predict genetic merit of young bulls. The variable used to weight DYD was DE_{PROG}, while the variable used to weight PTA was DE_{PTA}. The weight for regression when heterogeneous variance is present is $\frac{1}{\sigma^2}$. The variance of DYD is $VAR(DYD) \simeq \frac{\sigma^2}{DE_{PROG}}$. Thus, the correct weight for DYD is $\frac{DE_{PROG}}{\sigma^2}$. Because, σ^2 is constant it can be removed and DE_{PROG} becomes the weight for DYD. Similarly, REL is the correct weight for PTA to account for the heterogeneous variance of the PTA.

Three analyses were performed on the data set. The first included compiling all first proofs on each bull regardless of when the bull received his first proof (Winter 90 to Summer 91). A single weighted regression analysis was run for first DYD or PTA on the estimate for each pedigree source from the immediately prior summary. First proofs in Winter 1990 were regressed on Summer 1989 pedigree estimates; first proofs in Summer 1990 on pedigrees from Winter 1990; first proofs in Winter 1991 on pedigrees from Summer 1990; and first proofs in Summer 1991 on pedigrees from Winter 1991. By using the pedigree estimate just prior to the summary the bull received his first proof the most recent information on the parents that was not influenced by the proof of the young bull was used. The regression coefficients and R^2 were computed to determine how well the first proof on a young bull can be predicted and which pedigree source is the best predictor.

The second analysis was to see if date of first proof affects the relationship between first PTA or DYD and the different sources of pedigree information. The bulls were divided into four groups based on the date of the USDA AM summary they received their first official proof. This resulted in 416 bulls getting their first proof in Winter 1990, 390 in Summer 1990, 403 in Winter 1991, and 435 in Summer 1991. Separate weighted regressions for milk, fat, and protein PTA and DYD from first proofs on the different sources of pedigree information from Summer 1989 were run for each group of bulls. Regression coefficients and R^2 were evaluated to determine which pedigree source predicted the different measures of bull genetic merit most accurately.

Estimating the regression for each group separately allowed the effect of the changes to the method of calculating the AM evaluations in January and July 1991 to be evaluated. The adjustment in Winter 1991 was to eliminate the "rip dip" experienced by bulls with many first lactation daughters in early lactation (VanRaden et al., 1991). Since many of the bulls in the data set had proofs based on in progress first lactation production, the effect of this change on the relationship between the bulls and ancestors was investigated. The change in the Summer 1991 summary was to adjust for heterogeneous within herd variance (Wiggans and VanRaden, 1991). This adjustment reduced the PTAs of high PTA cows in high variance herds. These are cows likely to be selected as bull dams. The adjustment should have lesser effect on the PTAs' and DYDs' of bulls.

The third analysis included only the 435 bulls with first proofs occurring in Summer 1991. The PTAs and DYDs for milk, fat, and protein were regressed on the pedigree estimates from each USDA AM summary (Summer 1989 to Winter 1991). This enabled the relationship between son and parents to be evaluated as the parents' evaluations increased in accuracy. Because of the time involved in progeny testing, A.I. bulls are selected based on a pedigree estimate five years before the bull gets an official proof. The regression based on Summer 1989 pedigree information and Summer 1991 proofs was as close to this situation as the data would allow. Thus, this particular analysis resulted in regressions of bull's first PTA and DYD on pedigrees estimated from .5 to 2 years before the bull received an official proof. The latter analysis was repeated using only first proofs in Winter 91 to obtain a result that wasn't affected by the adjustment for heterogeneous within herd variance.

Determination of the effect of granddaughter information from sons on the PTA of the bull dam

Information from all relatives impact the genetic evaluation of individuals in the USDA AM. Of particular interest was the impact of the daughters of a young bull on the bull dam. The magnitude of this impact was investigated because it was suspected some bull dams are treated preferentially. This preferential treatment causes the PTA of the dam to be biased above her true transmitting ability. The dam's PTA will then overestimate the son's PTA. The average reliability of bull dams is less than the average reliability of sires of sons. Therefore, the PTA of the dam is more influenced than the PTA of the sire by granddaughter performance information. Having many granddaughters with lactation records randomly assigned to different herds will bring the dam's PTA more in line with her true transmitting ability. The amount of influence granddaughter performance has on a bull dam's genetic evalution depends on the amount of information in each son's proof. Another source of change in the PTA of bull dams is daughter information. The dam may be adding information from daughters with lactation records to her proof. Although contributions to the PTAs of cows also comes from parent information and individual records, in the animal model the cows' first five lactations only are used to evaluate the PTA. By the time the son receives daughter information most bull dams have completed five lactations so her own records would not likely contribute to change in her PTA. The parent information on the bull dam is not expected to be the cause of changes in her PTA due to this information changing very little by the time the bull dam has granddaughter performance information. Therefore, although the entire change in the PTA_{DAM} cannot be accounted for by grandaughter performance it was suspected it would have a significant impact on the PTA_{DAM}

To determine the effect of granddaughter information on the PTA of the dam, dam's ID, PTAs and RELs for Summer 1989 to Summer 1991 were collected for the 1,644 bulls in the data set. The DE_{PTA} and DE_{PROG} along with the PTA, DYD and PA for milk was collected for all sons of each dam in the data at every USDA AM summary date from Summer 1989 to Summer 1991. Note, that the bull dams used were the dams of the 1,644 bulls in the data set that were not progeny tested outside of each A.I. organization's designated young sire sampling herds. However, the bulls used to measure the impact of granddaughter performance on the bull dams were **all** sons of the dam that had at DYDs and PTAs. Dams who had granddaughter performance information in Summer 1989 were excluded. This left a total of 807 bull dams for evaluation. For each dam, the mean DYD of all her sons ($\overline{DYD}_{SONS}$) and the total DE_{PTA} ($\sum DE_{PTA\_SONS}$) and DE_{PROG} ($\sum DE_{PROG\_SONS}$) of all her sons was collected at each USDA AM summary date from Winter 1990 to Summer 1991. For each PTA_{DAM} from Winter 1991 to Summer 1991 the prior PTA was subtracted (ΔPTA_{DAM}). To obtain an estimate of the granddaughter performance with the average PA of the sons removed, the

PA from the AM evaluation previous the PTA or DYD being used was subtracted from the PTA or DYD. The mean of these variables were calculated for each dam from Winter 1990 to Summer 1991 and designated as $\overline{PTA_{SONS} - PA_{SONS}}$ and $\overline{DYD_{SONS} - PA_{SONS}}$. Additionally, the Summer 89 PA was subtracted from the Summer 91 PTA and DYD. To best show the impact of granddaughter performance on the PTA_{DAM} the resulting data set of bull dams was divided into groups by the first USDA AM sire summary date the dam received granddaughter performance information. The first group of 203 bull dams had no granddaughter performance information in Summer 1989 and received their first granddaughter information in Winter 1990. The second group of 212 bull dams had no granddaughter performance information in Summer 1989 or Winter 1990 and received their first granddaughter information in Summer 1990. The third group of 195 bull dams had no granddaughter performance information in Summer 1989, Winter 1990 or Summer 1990 and received their first granddaughter information in Winter 1991. Finally, the fourth group of 197 bull dams had no granddaughter performance information in Summer 1989, Winter 1990, Summer 1990 or Winter 1991 and received their first granddaughter information in Summer 1991. Using weighted regression each ΔPTA_{DAM} for all dams in each group were regressed on $\overline{DYD_{SONS}}$, $\overline{PTA_{SONS} - PA_{SONS}}$ or $\overline{DYD_{SONS} - PA_{SONS}}$. The variable used to weight the regressions were $\sum DE_{PTA\_SONS}$ for variables involving PTA of sons and $\sum DE_{PROG\_SONS}$ for variables involving DYD of sons. The following regression equation was used:

$$\Delta PTA_i = \alpha + \beta x_i + e_i$$

where:

ΔPTA = change in PTA for the i^{th} dam weighted by ΣDE_{PTA_SONS} or ΣDE_{PROG_SONS},

α = y intercept,

β = regression coefficient,

x_i = $\overline{DYD_{SONS}}$, $\overline{PTA_{SONS} - PA_{SONS}}$ or $\overline{DYD_{SONS} - PA_{SONS}}$ of all sons for the i^{th} dam,

e_i = error for the i^{th} dam.

The regression coefficients and R^2 values were used to interpret the effect of granddaughter performance information on a bull dam.

Determination of evidence of bias in evaluations of bull dam's or different groups of bulls.

To determine if any potential the evidence of bias in cow evaluations was more prevalent for some bull dams or groups of bulls than others the average difference between the Summer 1991 PTA or DYD and the Summer 1989 PA ($\overline{PTA - PA}$) and ($\overline{DYD - PA}$) weighted by DE_{PTA} or DE_{PROG} were evaluated for three different comparisons. Because of the wide variation in the accuracies of PTAs and DYDs in the data weighted means were used for this objective. Observations were weighted by the DE_{PROG} in Summer 1991. Observations for PTA - PA were weighted by the DE_{PTA} in Summer 1991. The Summer 1991 PTAs and DYDs for milk, fat, and protein were used because these estimates had the most accuracy for each bull. The Summer 1989 PA estimates were used for this objective because they were the only PA estimates free of influence from the bull's progeny for all bulls in the data set. Also, the Summer 1989 PA estimates were the closest AM evaluation estimates to the time the bull was selected to be progeny tested. Thus, this estimate of PA was the most logical choice for predicting the future progeny performance of the bull. For a group of bulls, the expected value of $\overline{PTA - PA}$ and $\overline{DYD - PA}$ are zero. However, for individual bulls Mendelian sampling, errors or biases in estimating the son, sire, and dam proofs could cause the PTA - PA and DYD - PA to be significantly different from zero. Because most sires of sons have a REL near one, most of the errors or biases come from the estimation of the dam whose REL seldomly approaches one. However, the $\overline{PTA - PA}$ or $\overline{DYD - PA}$ provide only limited information on the possibility of bias. The first comparison involved the 103 heavily sampled bulls versus the 1,624 bulls sampled in designated young sire sampling herds. It was expected that as a group the PA overestimates the true transmitting ability of the heavily sampled bulls because of preferential treatment given the dam. To determine if this was true, the $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ were used to see if heavily sampled bulls tended to be more negative for the variables than the other bulls. The second comparison was of the bulls at different A.I. organizations. The 1,644 bulls were divided into 9 groups by the A.I. organizations that sampled them and compared to see if there were any significant differences in the $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ of progeny test bulls at different A.I. organizations. Finally, the third comparison involved comparing groups of dams based on rank of PTAs for milk, fat, and protein. The dams were ranked by the PTAs for the same trait (milk, fat, or protein) the $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ were divided into four equal groups of 411 bulls for milk and fat and 406 bulls for protein. Again, $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ were used to determine any significant differences in the bulls grouped by rank of PTA_{DAM} for milk, fat and protein.

Results and Discussion

Predicting bulls' first estimate of genetic merit for yield traits from different sources of pedigree information.

Means and SDs for first proofs and pedigree information immediately prior to each bull's first proof are in Table 5. There were 1,644 bulls who received first daughter information for milk and fat from Winter 1990 to Summer 1991. Only 1,585 of these bulls had enough daughters (10 or more) with protein information to have a first DYD for protein calculated from Winter 1990 to Summer 1991.

For milk, fat and protein, the mean PA was higher than the mean PI. PA estimates for 100% of the genes the bull receives; PI only 75%. This produces a larger standard deviation (SD) for PA than PI, which can be seen in Table 5. Additionally, the larger SD for PA versus PI was also a result of the greater accuracy in estimating the PTA_{SIRE} and PTA_{MGS} than the PTA_{DAM}, which caused less variation in PI than PA. The average PTA_{SIRE} was greater than the average PTA_{DAM}. This was a result of more selection pressure possible on the sire than on the dam. For milk, fat and protein, the mean first DYD was lower than the mean first PTA indicating the PA is having a positive influence on the outcome of the PTA.

Table 5. Means and SD of immediately prior pedigree and first proof genetic values for milk, fat, and protein for all bulls.

	Milk		Fat		Protein	
	Mean	SD	Mean	SD	Mean	SD
Prior pedigree						
PA (kg)	526	189	19.4	7.6	15.1	5.4
PI (kg)	410	142	13.6	5.8	11.6	4.0
PTA_{SIRE} (kg)	626	243	21.4	10.2	17.5	6.2
PTA_{DAM} (kg)	427	275	17.4	10.6	12.7	8.2
REL_{PA} (%)	40.9	2.2	40.9	2.2	40.4	2.4
REL_{SIRE} (%)	98.9	1.0	98.9	1.0	98.9	1.1
REL_{DAM} (%)	64.6	8.7	64.6	8.7	61.9	9.5
First proof						
DYD (kg)	464	347	15.6	11.7	11.2	9.8
PTA (kg)	494	228	17.4	8.2	13.5	6.4
DE_{PROG}	15.7	7.8	15.7	7.8	14.8	7.4
DE_{PTA}	25.9	7.9	25.9	7.9	24.8	7.5
REL (%)	63.6	6.7	63.6	6.7	62.7	6.6
n	1644		1644		1585	

Regression coefficients and R^2 for regressing first DYD or first PTA for milk, fat and protein weighted by DE_{PROG} or DE_{PTA} on immediately prior PA, PI, PTA_{SIRE}, or PTA_{SIRE} and PTA_{DAM} are in Table 6. The PA was a substantially better predictor (higher R^2) than the PI for both first DYD and first PTA of milk, fat and protein. Because PI was less variable than PA the weights were higher for PI than PA to predict first DYD and first PTA for each trait, but the higher R^2 for PA indicated that it accounted for more of the variation in the dependent variables. Adding PTA_{DAM} to the model with PTA_{SIRE} resulted in a higher R^2 than the model containing only the PTA_{SIRE} for both first DYD and first PTA of milk, fat and protein. The higher coefficients and R^2s for first PTA compared to first DYD were a result of the PAs inclusion in the calculation of the PTAs. This part-whole relationship was responsible for much of the increased accuracy of prediction.

Although the coefficients and R^2 were less than expected, it was evident that reasonable accuracy could be obtained from predicting progeny test bull's first animal model (AM) evaluation of genetic merit for milk, fat and protein from pedigree information. It was expected that the R^2s would increase as DE_{PROG} increased in later AM evaluations. PA was a better predictor of son's genetic evaluation than PI and should be used in selecting young bulls for progeny testing.

Predicting genetic merit milk for bulls grouped by date of first proof from different sources of pedigree information.

Table 7 contains the means and SD for milk of pedigree estimates and genetic merit estimates for the 1,644 bulls divided into groups by the date the bull received its first proof. Genetic improvement was seen for sires and dams for each succesive group of bulls. Also, the increase in the mean DYD and PTA from each group of bulls to the next indicated genetic advancement for milk was occuring with the animal model.

Table 6. Regression coefficients and R^2 of first DYD and PTA on pedigree estimates immediately prior to the bull's first proof.

	Regression Coefficients				
	PA	PI	PTA_{SIRE}	PTA_{DAM}	R^2
First DYD[a]					
Milk	.72				.17
Milk		.73			.09
Milk			.38		.07
Milk			.35	.37	.17
Fat	.67				.20
Fat		.71			.13
Fat			.40		.12
Fat			.37	.30	.20
Protein	.73				.18
Protein		.80			.11
Protein			.47		.09
Protein			.40	.34	.18
First PTA[b]					
Milk	.84				.47
Milk		.85			.27
Milk			.45		.22
Milk			.42	.42	.47
Fat	.81				.54
Fat		.84			.33
Fat			.46		.31
Fat			.44	.38	.54
Protein	.84				.49
Protein		.86			.27
Protein			.51		.23
Protein			.44	.41	.49

[a]DYD weighted by DE_{PROG}
[b]PTA weighted by DE_{PTA}

Table 7. Means and SD for genetic parameters for milk of bulls grouped by date of first proof.

	Date of First proof							
	Winter 90 n=416		Summer 90 n=390		Winter 91 n=403		Summer 91 n=435	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Summer 89								
PA (kg)	467	196	497	177	533	178	546	166
PI (kg)	357	152	382	136	404	131	420	116
PTA_{SIRE} (kg)	565	277	595	248	610	237	622	187
PTA_{DAM} (kg)	369	263	399	254	455	271	470	252
Winter 90								
PA (kg)	465	191	492	173	536	175	555	168
PI (kg)	350	149	377	133	405	129	423	111
PTA_{SIRE} (kg)	557	270	590	240	616	230	631	174
PTA_{DAM} (kg)	373	267	395	251	455	272	478	266
DYD (kg)	418	305	-	-	-	-	-	-
PTA (kg)	434	216	-	-	-	-	-	-
Summer 90								
PA (kg)	469	193	498	178	548	180	572	177
PI (kg)	361	151	391	136	425	135	445	118
PTA_{SIRE} (kg)	574	272	612	244	648	239	668	186
PTA_{DAM} (kg)	363	271	384	260	449	280	476	278
DYD (kg)	414	309	445	329	-	-	-	-
PTA (kg)	431	251	473	226	-	-	-	-
Winter 91								
PA (kg)	487	202	516	184	563	181	593	181
PI (kg)	374	158	406	141	443	142	464	122
PTA_{SIRE} (kg)	595	283	636	253	676	250	697	189
PTA_{DAM} (kg)	379	282	396	269	449	284	488	288
DYD (kg)	460	322	480	316	475	374	-	-
PTA (kg)	466	272	491	251	520	224	-	-
Summer 91								
PA (kg)	481	194	511	173	547	170	574	168
PI (kg)	377	156	408	139	445	141	465	120
PTA_{SIRE} (kg)	597	280	638	249	678	248	696	187
PTA_{DAM} (kg)	366	267	382	252	416	261	451	265
DYD (kg)	491	308	520	293	480	303	516	369
PTA (kg)	488	268	517	247	501	238	548	228

The large SD for the first DYD in the groups with first proofs in Winter 1991 and Summer 1991 coincide with the adjustment to the variance of records in progress (RIP) which was implemented for these two AM evaluations (VanRaden et al., 1991). This change was to expand the variance of extended records from RIPs so the genetic variance of the RIPs equaled the variance of complete records. The purpose was to prevent large fluctuations in the PTA's of individuals, especially when a large portion of their evaluations consisted of RIPs. First proofs of bulls contained large numbers of daughters with RIPs. The decrease in the mean and SD of the PTA_{DAM} from Winter 91 to Summer 91 for each group coincided with the adjustment for heterogeneous variance which was implemented for the Summer 91 AM evaluation (Wiggans and VanRaden, 1991). This change tended to decreased the PTA of cows whose records were in large herds with high average herd yield. Cows selected as dams of young bulls tend to come from herds with above average within herd variation (Powell et al., 1983). The decrease in the means of PTA_{DAM} for each group of bulls at implementation of the adjustment for heterogeneous within herd variance (Summer 91) suggested that the adjustment stabilized genetic evaluations of bull dams. The gradual increase in the mean PTA_{SIRE} within each group with time was unexplained considering the sires had a mean REL of 99% by Summer 89.

The decreasing SD of PTA_{SIRE} across the four groups of bulls was a result of more intensive selection to propagate each successive group of bulls. Sires which had more than 30 sons in the total data set are in Table 8. Sires are in descending order by the number of sons in the total data set. The total number of sons were divided into four groups based on the AM summary the bull received his first proof. Overall, the 6 sires with the most sons in the entire data comprised 58.6% of bulls. These same sires accounted for 42.5%, 49.7%, 70.5% and 70.8% of the bulls who received first proofs in Winter 90, Summer 90, Winter 91 and Summer 91, respectively. Additionally, the two most prominant sires of sons in each group sired 31.0%, 29.5%, 40.7% and 51.7% of the bulls in the four groups, respectively. There was a tendency to increase the number of sons by the top sires over the short duration of this study.

Table 8. Sires siring more than 30 bulls in the data by first evaluation date of young bulls.

Sire	Sons each run				Total	Name
	Winter 90	Summer 90	Winter 91	Summer 91		
1806201	0	4	69	130	203	NED BOY
1773417	5	31	95	62	193	MARK
1697572	11	26	42	95	174	ROTATE
1682485	32	72	35	12	151	TRADITION
1665634	63	37	17	5	122	BOVA
1650414	66	24	26	4	120	VALIANT
1747862	46	24	9	4	83	ENCHANTMENT
1765326	37	31	13	1	82	MEMORIAL
1811754	15	43	7	8	73	VALOR
1667366	11	7	14	16	48	BELL
1721509	14	9	15	7	45	JETSON
1723741	21	12	3	1	37	CHAIRMAN
1754029	0	4	13	15	32	JASON
Total	321	324	358	360	1363	
All others	95	66	45	75	281	
Overall Total	416	390	403	435	1644	

Means and SD for reliability (REL) and daughter equivalents (DE) for milk and fat of the bulls grouped by date of first proof are in Table 9. Means and SDs of REL for the pedigree estimates were similar for each group of bulls. Mean REL_{SIRE} remained relatively constant over successive proofs while, the mean REL_{DAM} increased 10 to 12% over the four proofs. The change in REL_{DAM} resulted from new information on sons, daughters, grandprogeny, and perhaps her own records.

Most A.I. bulls are 5 years of age when they receive their first proof. If the average age of young bulls' sires were 6 to 8 years when the young bulls were born, most sires will be 11 to 13 years old when their sons get a proof. The average REL of sires of sons at this age is near 99%. Therefore, additional information from a son impacts on his sire's PTA very little. Dams are generally 3 to 5 years old when their sons are born. When the son receives a first proof, the dams would be 8 to 10 years old. At this point, the only contribution to her PTA which causes large changes is the progeny contribution (PC). The PA is generally fixed by this time. The contribution to her PTA from her own records would not change because only the first 5 lactations contribute in the AM evaluation. Although the upper limit of the REL_{DAM} is 99%, it seldom approaches this value because cows seldom produce sufficient progeny information to have a REL greater than 90%. The average dam in this study had a REL of approximately 65%. At this point, progeny information can still have a significant impact on the PTA of the dam.

Means and SD for REL of the bulls first proof in each group was similar with a range from 61.7% to 65.0%. It was evident from the increase in average DE_{PROG} from one proof to the next within each group of bulls that the bulls were gradually adding first crop daughters from each proof to the next. Although the impact to REL was smaller than adding additional daughters, part of the increase was due to daughters completing or adding additional records.

Regression coefficients and R^2 for predicting DYD milk weighted by DE_{PROG} from different pedigree sources are shown in Table 10. Coefficients and R^2 for each group's first proof are on the diagonal. Second and/or later proofs are on the off-diagonal. The pedigree information used was

Table 9. Means and SD for REL and daughter equivalents (DE) for milk and fat of bulls grouped by date of first proof.

	Date of First proof							
	Winter 90 n=416		Summer 90 n=390		Winter 91 n=403		Summer 91 n=435	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Summer 89								
REL_{PA} (%)	40.8	2.4	39.9	1.9	39.7	1.9	39.4	1.9
REL_{SIRE} (%)	98.8	1.9	99.0	0.3	98.9	0.8	98.9	0.9
REL_{DAM} (%)	64.2	9.5	60.8	7.7	59.8	7.7	58.6	7.5
Winter 90								
REL_{PA} (%)	42.0	2.3	40.7	2.0	40.3	2.0	40.1	2.0
REL_{SIRE} (%)	98.9	1.8	99.0	0.2	98.9	0.7	99.0	0.4
REL_{DAM} (%)	69.0	9.0	64.0	8.0	62.4	7.9	61.6	7.9
DE_{PROG}	15.2	7.3	-	-	-	-	-	-
DE_{PTA}	25.3	7.4	-	-	-	-	-	-
REL (%)	63.2	6.4	-	-	-	-	-	-
Summer 90								
REL_{PA} (%)	42.6	2.3	41.7	1.9	40.9	2.1	40.6	2.1
REL_{SIRE} (%)	98.9	1.8	99.0	0.2	98.9	0.7	99.0	0.2
REL_{DAM} (%)	71.4	9.1	68.0	7.8	64.5	8.3	63.5	8.5
DE_{PROG}	32.2	12.4	17.0	8.7	-	-	-	-
DE_{PTA}	42.7	12.5	27.1	8.8	-	-	-	-
REL (%)	74.3	4.9	64.4	7.1	-	-	-	-
Winter 91								
REL_{PA} (%)	42.8	2.3	42.2	1.9	41.7	2.0	41.1	2.2
REL_{SIRE} (%)	98.9	1.8	99.0	0.2	98.9	0.7	99.0	0.1
REL_{DAM} (%)	72.5	9.1	69.9	7.8	68.0	8.1	65.5	8.8
DE_{PROG}	40.3	16.9	32.0	13.4	13.6	6.5	-	-
DE_{PTA}	50.9	17.0	42.2	13.5	23.7	6.7	-	-
REL (%)	77.3	5.0	74.0	5.4	61.7	6.4	-	-
Summer 91								
REL_{PA} (%)	43.3	2.3	42.7	1.9	42.6	2.0	42.3	2.1
REL_{SIRE} (%)	98.9	1.7	99.0	0.2	98.9	0.6	99.0	0.1
REL_{DAM} (%)	74.1	9.0	72.0	7.8	71.5	8.2	70.3	8.6
DE_{PROG}	50.7	25.7	45.8	21.6	33.4	11.0	17.2	8.1
DE_{PTA}	61.4	25.8	56.3	21.6	43.9	11.1	27.5	8.2
REL (%)	80.2	4.9	78.8	5.1	74.9	4.9	65.0	6.7

estimated in Summer 89 before any of the bulls had daughter information. For each DYD milk, PA was a more accurate predictor than the PI or the PTA_{SIRE} alone. Placing PTA_{SIRE} and PTA_{DAM} in the model together resulted in an R^2 equal to or similar to the R^2 for PA. The weights for PTA_{SIRE} and PTA_{DAM} were less than .5. In most cases, the weight for PTA_{SIRE} was greater than the PTA_{DAM}, except for bulls with first proof in Winter 91. For these bulls, the weight for PTA_{DAM} was .27, while the weight for PTA_{SIRE} was .19. When this group of bulls received second proofs in Summer 91 the weights were .29 for PTA_{SIRE} and .24 for PTA_{DAM} which were similar to the other groups of bulls. As the bulls in each group received additional daughter information the coefficients and R^2 tended to increase, except for the bulls receiving first proof in Summer 90. This decrease in R^2 for the Summer 90 group was small and unexplained. Additionally, the higher regression coefficient of .82 for PA for the Summer 90 group of bull was unexplained. Overall, the pedigree information was constant (Summer 89) for each group of bulls, but the accuracy of the DYD was increasing as a result of additional daughters and/or current daughters completing or adding lactations. This resulted in higher R^2 for most groups becaus the variation in DYD decreased with each successive AM evaluation.

The low coefficients and R^2 for the bulls with first proofs in Winter 91 coincide with the changes in the AM evaluation to expand the variance of RIPs. The changes in the evaluation system may have decreased the relationship between young bulls' and their ancestors. This group had the largest SD for DYD and the lowest mean and SD for DE_{PROG} for first proof. The large SD in DYD which occured at the same AM evaluation as the adjustment for RIPs and the lower accuracy of these DYDs may have caused the low coefficients and R^2. Another condition which may have been a factor was that 70.5% of the bulls were sired by only 6 sires. The entire group of bulls was sired by a total of 30 sires. Although, the R^2s for this group did increase for the second AM evaluation for the group, the R^2s did not recover to the level of the R^2s for the first two groups.

The low R^2 for the bulls receiving first proofs in Summer 91 coincide with the implementation of adjusting for heterogeneous variance in the AM evaluations. This group also was sired by only a few sires: 70.8% of the bulls by 6 sires compared to 42.5% and 49.7% for the first two groups,

Table 10. Regression coefficients and R^2 of DYD milk on Summer 89 pedigree estimates for bulls grouped by date of first proof.

		Date of DYD[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	416												
PA		.68	-	.19	.73	-	.21	.78	-	.22	.81	-	.25
PI		.76	-	.15	.81	-	.15	.87	-	.16	.89	-	.18
PTA_{SIRE}		.35	-	.11	.41	-	.13	.45	-	.14	.45	-	.15
PTA_{SIRE} and PTA_{DAM}		.35	.33	.19	.39	.34	.21	.43	.36	.22	.43	.38	.25
Summer 90	390												
PA		-	-	-	.82	-	.20	.78	-	.19	.69	-	.17
PI		-	-	-	.83	-	.12	.86	-	.14	.75	-	.12
PTA_{SIRE}		-	-	-	.46	-	.12	.48	-	.14	.41	-	.12
PTA_{SIRE} and PTA_{DAM}		-	-	-	.45	.37	.20	.47	.31	.20	.41	.28	.18
Winter 91	403												
PA		-	-	-	-	-	-	.47	-	.06	.51	-	.09
PI		-	-	-	-	-	-	.42	-	.02	.54	-	.05
PTA_{SIRE}		-	-	-	-	-	-	.18	-	.02	.28	-	.04
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.19	.27	.06	.29	.24	.09
Summer 91	435												
PA		-	-	-	-	-	-	-	-	-	.67	-	.11
PI		-	-	-	-	-	-	-	-	-	.80	-	.07
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.43	-	.05
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.36	.32	.11

[a]DYD weighted by DE_{PROG}

respectively. Additionally, only two sires sired 51.7% of the bulls in this group, which resulted in a low SD (187 kg) for PTA_{SIRE}.

The regression coefficients and R^2 of PTA milk weighted by DE_{PTA} on Summer 89 pedigree estimates for bulls grouped by date of first proof, shown in Table 11, were higher than those for DYD milk, but showed a similar pattern. The R^2 were higher because the PA is included in the PTA function. Thus, there is a direct part-whole relationship between PTA and any pedigree estimates containing the sire and/or dam PTAs. For each group that received second or later proofs, the R^2 for each respective model decreased relative to the first proof on each group. This was primarily a result of the PA receiving less weight in the PTA function as more daughter information is added. Thus, the part-whole relationship is reduced.

Prediction of genetic merit fat for bulls grouped by date of first proof from different sources of pedigree information.

Means and SD for pedigree information and genetic merit fat for bulls grouped by date of first proof are in Table 12. Trends for fat were similar to those of milk. As with milk, the SD for the group of bulls receiving their first DYD fat in Winter 91 was larger than the SD for the other groups of bulls when they received their first proof. The lowest SD for first DYD fat was for the group receiving first proofs in Summer 91, which was not the case for milk.

In Table 13 are the regression coefficients and R^2 values for DYD fat weighted by DE_{PROG} on Summer 89 pedigree information for bulls grouped by date of first proof. Coefficients and R^2 tended to be lower than those for milk in the first two groups and higher than those for milk in the last two groups. The weights and R^2 for PA in the group receiving first proofs in Winter 91 were lower than the other groups. In most cases PA was a better predictor than PI for DYD fat, except for those bulls receiving first proofs in Winter 91 where the R^2 was .08 for PA vs. .11 for PI. This

Table 11. Weighted regressions and R^2 of PTA milk on Summer 89 pedigree estimates for bulls grouped by date of first proof.

		Date of PTA[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	416												
PA		.82	-	.55	.79	-	.38	.82	-	.35	.80	-	.34
PI		.85	-	.36	.84	-	.26	.89	-	.25	.85	-	.23
PTA_{SIRE}		.43	-	.30	.43	-	.23	.46	-	.22	.44	-	.21
PTA_{SIRE} and PTA_{DAM}		.41	.41	.55	.41	.38	.38	.44	.38	.35	.42	.38	.34
Summer 90	390												
PA		-	-	-	.88	-	.48	.84	-	.35	.75	-	.29
PI		-	-	-	.86	-	.27	.88	-	.23	.80	-	.19
PTA_{SIRE}		-	-	-	.46	-	.26	.48	-	.22	.43		.19
PTA_{SIRE} and PTA_{DAM}		-	-	-	.46	.42	.48	.48	.37	.36	.43	.32	.30
Winter 91	403												
PA		-	-	-	-	-	-	.75	-	.35	.62	-	.22
PI		-	-	-	-	-	-	.74	-	.19	.66	-	.13
PTA_{SIRE}		-	-	-	-	-	-	.35	-	.14	.34	-	.11
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.36	.38	.35	.34	.29	.22
Summer 91	435												
PA		-	-	-	-	-	-	-	-	-	.77	-	.31
PI		-	-	-	-	-	-	-	-	-	.87	-	.19
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.47	-	.15
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.41	.37	.31

[a]PTA weighted by DE_{PTA}

Table 12. Means and SD for genetic parameters for fat of bulls grouped by date of first proof.

	Date of First proof							
	Winter 90 n=416		Summer 90 n=390		Winter 91 n=403		Summer 91 n=435	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Summer 89								
PA (kg)	15.3	6.1	17.4	6.5	20.8	7.1	22.3	6.6
PI (kg)	10.2	4.3	11.8	4.8	14.4	5.3	16.0	4.7
PTA_{SIRE} (kg)	16.1	7.5	18.4	9.2	22.4	9.8	25.3	8.4
PTA_{DAM} (kg)	14.4	9.5	16.4	10.0	19.2	11.0	19.4	9.9
Winter 90								
PA (kg)	15.2	5.8	17.3	6.5	21.9	7.2	22.7	6.7
PI (kg)	9.9	4.4	11.6	4.9	14.4	5.5	15.9	4.7
PTA_{SIRE} (kg)	15.7	7.4	18.1	9.3	22.5	9.9	25.3	8.4
PTA_{DAM} (kg)	14.6	9.2	16.4	9.9	19.4	10.9	20.0	10.0
DYD (kg)	12.9	10.2	-	-	-	-	-	-
PTA (kg)	13.8	6.8	-	-	-	-	-	-
Summer 90								
PA (kg)	15.1	5.9	17.2	6.6	21.3	7.5	23.1	7.0
PI (kg)	10.2	4.5	12.0	5.2	15.0	5.8	16.7	5.0
PTA_{SIRE} (kg)	16.1	7.7	18.8	9.8	23.5	10.5	26.6	8.9
PTA_{DAM} (kg)	14.0	9.4	15.6	10.2	19.1	11.2	19.7	10.5
DYD (kg)	12.4	10.1	14.2	10.3	-	-	-	-
PTA (kg)	13.1	7.9	15.7	7.4	-	-	-	-
Winter 91								
PA (kg)	15.4	6.2	17.4	6.7	21.4	7.5	23.5	7.2
PI (kg)	10.4	4.7	12.4	5.4	15.5	6.0	17.2	5.2
PTA_{SIRE} (kg)	16.5	7.9	19.7	10.2	24.3	10.9	27.4	9.1
PTA_{DAM} (kg)	14.2	9.8	15.7	10.4	18.5	11.0	19.6	10.7
DYD (kg)	13.4	10.7	14.5	10.8	16.4	12.6	-	-
PTA (kg)	13.8	8.8	15.5	8.7	19.1	8.4	-	-
Summer 91								
PA (kg)	15.3	6.1	17.4	6.7	21.4	7.5	23.5	7.2
PI (kg)	10.7	4.8	12.6	5.4	15.7	6.0	17.2	5.1
PTA_{SIRE} (kg)	16.9	8.1	19.4	10.1	24.4	10.9	27.3	8.9
PTA_{DAM} (kg)	13.7	9.3	15.1	9.9	16.7	9.8	17.8	9.9
DYD (kg)	14.4	10.4	16.0	10.5	16.6	11.1	18.8	8.0
PTA (kg)	14.5	8.9	16.4	8.9	17.8	9.0	20.8	8.4

group had the highest SD for PI (6.0 kg), the highest SD for DYD (12.6 kg) and the lowest mean and SD for DE_{PROG} (13.6, 6.5) on their first proof than the other three groups of bulls. The R^2 for PA and PI were similar (.10 vs. .11, respectively) when this group received a second proof in Summer 91. For this group the weight for PTA_{DAM} in the regressions of DYD fat on PTA_{SIRE} and PTA_{DAM} was considerably lower than the weight for PTA_{DAM} in the other groups. Overall, regression coefficients for PTA_{SIRE} and PTA_{DAM} were equivalent for the Winter 90 and Summer 90 bulls, while the coefficient for PTA_{DAM} was considerably less than than the coefficient for PTA_{SIRE} in the Winter 91 and Summer 91 groups of bulls. This result indicated the PTA_{DAM} had poorer predictive ability of son's DYD fat in the latter two groups of bulls.

Table 14 contains the regression coefficients and R^2 values of PTA fat weighted by DE_{PTA} on Summer 89 pedigree information for bulls grouped by date of first proof. The results were similar, but the weights and R^2 were slightly lower than the results for PTA milk. The increase in the SD of PTA at each successive AM evaluation on each group resulted in decreased R^2 for second and later AM evaluations within each group.

Predicting genetic merit protein for bulls grouped by date of first proof from different sources of pedigree information.

Means and SDs for genetic merit and pedigree estimates of protein for bulls grouped by date of first proof are in Table 15. The trends in protein were similar to those for milk and fat. Again, the group with the largest SD for first DYD was the group with first proofs in Winter 91. The second largest SD for first DYD was the group with first proofs in Summer 91. This was in contrast to the results in fat, but in agreement with the results for milk.

Means and SDs in Table 16 for protein are for REL of pedigree estimates and bulls' PTA and DEs for bulls grouped by date of first proof. Results were lower than those for milk and fat. There were relatively few differences, however, in the REL_{SIRE} for the three traits. The lowest mean for REL

Table 13. **Regression coefficients and R^2 of DYD fat on Summer 89 pedigree estimates for bulls grouped by date of first proof.**

		Date of DYD[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	416												
PA		.59	-	.13	.59	-	.13	.61	-	.12	.62	-	.14
PI		.64	-	.08	.49	-	.05	.55	-	.05	.59	-	.06
PTA_{SIRE}		.33	-	.06	.29	-	.05	.32	-	.05	.34	-	.06
PTA_{SIRE} and PTA_{DAM}		.34	.27	.14	.29	.30	.13	.32	.29	.12	.35	.29	.14
Summer 90	390												
PA		-	-	-	.60	-	.15	.73	-	.19	.74	-	.21
PI		-	-	-	.41	-	.04	.59	-	.07	.64	-	.08
PTA_{SIRE}		-	-	-	.25	-	.05	.34	-	.08	.36	-	.09
PTA_{SIRE} and PTA_{DAM}		-	-	-	.27	.32	.15	.35	.38	.19	.37	.37	.21
Winter 91	403												
PA		-	-	-	-	-	-	.51	-	.08	.51	-	.10
PI		-	-	-	-	-	-	.74	-	.11	.71	-	.11
PTA_{SIRE}		-	-	-	-	-	-	.42	-	.12	.41	-	.12
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.44	.11	.13	.43	.14	.14
Summer 91	435												
PA		-	-	-	-	-	-	-	-	-	.66	-	.13
PI		-	-	-	-	-	-	-	-	-	.85	-	.10
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.44	-	.09
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.43	.27	.14

[a]DYD weighted by DE_{PROG}

Table 14. Regression coefficients and R^2 of PTA fat on Summer 89 pedigree estimates for bulls grouped by date of first proof.

		Date of PTA[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	416												
PA		.77	-	.47	.70	-	.29	.70	-	.24	.70	-	.23
PI		.79	-	.25	.64	-	.12	.68	-	.11	.71	-	.12
PTA_{SIRE}		.43	-	.23	.37	-	.12	.38	-	.11	.41	-	.12
PTA_{SIRE} and PTA_{DAM}		.43	.36	.48	.37	.34	.29	.38	.33	.24	.40	.31	.23
Summer 90	390												
PA		-	-	-	.78	-	.48	.80	-	.37	.78	-	.33
PI		-	-	-	.66	-	.19	.69	-	.15	.70	-	.14
PTA_{SIRE}		-	-	-	.36	-	.20	.36	-	.15	.37	-	.14
PTA_{SIRE} and PTA_{DAM}		-	-	-	.39	.39	.48	.40	.40	.37	.40	.38	.33
Winter 91	403												
PA		-	-	-	-	-	-	.78	-	.44	.64	-	.26
PI		-	-	-	-	-	-	.90	-	.33	.79	-	.22
PTA_{SIRE}		-	-	-	-	-	-	.48	-	.32	.44	-	.23
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.50	.30	.47	.46	.21	.30
Summer 91	435												
PA		-	-	-	-	-	-	-	-	-	.75	-	.36
PI		-	-	-	-	-	-	-	-	-	.90	-	.26
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.47	-	.23
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.46	.31	.37

[a]PTA weighted by DE_{PTA}

Table 15. Means and SD for genetic parameters for protein of bulls grouped by date of first proof.

	Date of First proof							
	Winter 90 n=397		Summer 90 n=379		Winter 91 n=392		Summer 91 n=417	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Summer 89								
PA (kg)	11.9	4.6	13.8	4.5	16.0	5.0	17.5	4.3
PI (kg)	9.6	3.3	11.1	3.2	13.0	3.7	14.4	3.0
PTA_{SIRE} (kg)	14.5	5.0	16.4	5.0	19.2	6.1	21.4	4.7
PTA_{DAM} (kg)	9.4	7.6	11.2	7.7	12.9	7.9	13.6	6.8
Winter 90								
PA (kg)	11.7	4.5	13.5	4.4	15.9	5.1	17.6	4.5
PI (kg)	8.3	3.2	9.8	3.2	11.9	3.7	13.4	3.0
PTA_{SIRE} (kg)	12.8	4.8	14.7	4.9	17.7	6.2	20.1	4.6
PTA_{DAM} (kg)	10.7	7.5	12.4	7.5	14.1	7.9	15.1	7.2
DYD (kg)	8.3	8.6	-	-	-	-	-	-
PTA (kg)	10.4	5.5	-	-	-	-	-	-
Summer 90								
PA (kg)	11.8	4.5	13.5	4.5	16.2	5.3	18.0	4.6
PI (kg)	8.6	3.4	10.2	3.3	12.4	3.9	14.0	3.0
PTA_{SIRE} (kg)	13.3	5.0	15.4	5.2	18.6	6.4	21.2	4.7
PTA_{DAM} (kg)	10.3	7.5	11.7	7.8	13.8	8.3	14.8	7.6
DYD (kg)	8.6	8.1	10.0	8.0	-	-	-	-
PTA (kg)	10.3	6.2	12.4	5.4	-	-	-	-
Winter 91								
PA (kg)	12.1	4.7	13.9	4.6	16.4	5.4	18.5	4.9
PI (kg)	8.9	3.5	10.5	3.5	12.9	4.1	14.5	3.2
PTA_{SIRE} (kg)	13.7	5.1	15.9	5.4	19.3	6.7	21.9	4.9
PTA_{DAM} (kg)	10.5	7.9	12.0	7.9	13.6	8.4	15.0	8.0
DYD (kg)	9.6	8.1	11.5	7.9	11.8	11.2	-	-
PTA (kg)	11.0	6.7	12.9	6.2	14.6	6.8	-	-
Summer 91								
PA (kg)	11.9	4.5	13.7	4.4	15.9	5.0	17.9	4.5
PI (kg)	8.9	3.5	10.6	3.5	12.9	4.0	14.4	3.1
PTA_{SIRE} (kg)	13.7	5.1	16.0	5.3	19.3	6.6	21.8	4.7
PTA_{DAM} (kg)	10.1	7.4	11.5	7.5	12.6	7.6	13.9	7.4
DYD (kg)	10.3	7.8	12.2	7.5	12.5	9.0	14.4	10.0
PTA (kg)	11.4	6.6	13.4	6.2	14.0	7.1	16.5	6.0

of PTA was 60.9% for the group of bulls with first proof in Winter 91. This group also had the lowest mean and SD for DE_{PROG}

Regression coefficients and R^2 values for predicting DYD protein weighted by DE_{PROG} from Summer 89 pedigree for bulls grouped by date of first proof are in Table 17. Compared to milk, the coefficients and R^2 values were lower for all groups, except the group of bulls with first proofs in Winter 91. The lowest R^2 values were for the group of bulls receiving first proofs in Summer 91. PA was a better predictor of DYD protein than PI in all cases. Adding PTA_{DAM} to the model with PTA_{SIRE} increased the R^2 values for predicting DYD protein similar to the R^2 values for PA.

The weights and R^2 for predicting PTA protein of bulls grouped by date of first proof in Table 18 were higher than those for DYD protein because of the part-whole relationship between PTA and pedigree information. R^2 were lower than those for predicting PTA fat and for the most part lower than the R^2 for predicting PTA milk of the different groups. Those bulls receiving first proofs in Winter 91 had a higher R^2 for predicting PTA protein than PTA milk.

The resulsts in Tables 10, 13 and 17 indicated prediction of first DYD milk, fat and protein for each group from PA gave the highest accuracies of prediction compared to PI and PTA_{SIRE} alone. The lower R^2 values for PI agreed with Funk and Hansen (1988). For first proofs of each group of bulls, the highest R^2 for PA were for milk, with fat second and protein last, except for the group receiving first proofs in Winter 91. This group had the highest R^2 for first DYD protein, DYD fat was second highest and DYD milk lowest. The lowest R^2s for PA to predict first DYD milk and fat were for the group of bulls with first proof in Winter 91 (.06 and .08, respectively). The lowest R^2 for PA to predict first DYD protein was for the group of bulls with first proof in Summer 91 (.05). The highest R^2s for PA to predict first DYD milk and fat were for the Summer 90 group (.20 and .15, respectively). The highest R^2 for PA to predict first DYD protein was in Winter 90 (.11). The R^2s between groups for protein are more homogeneous than R^2s between groups for milk or fat.

Table 16. Means and SD for REL and daughter equivalents (DE) for protein of bulls grouped by date of first proof.

	Date of First proof							
	Winter 90 n=397		Summer 90 n=379		Winter 91 n=392		Summer 91 n=417	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Summer 89								
REL_{PA} (%)	39.2	2.8	39.2	2.4	39.1	2.3	38.8	2.1
REL_{SIRE} (%)	98.8	2.0	98.9	0.3	98.9	1.2	98.9	0.9
REL_{DAM} (%)	60.7	11.0	58.0	9.4	57.6	9.1	56.5	8.3
Winter 90								
REL_{PA} (%)	41.4	2.5	40.2	2.1	39.9	2.2	39.7	2.1
REL_{SIRE} (%)	98.9	1.9	99.0	0.2	98.9	1.1	99.0	0.4
REL_{DAM} (%)	66.6	9.7	61.9	8.5	60.9	8.7	60.0	8.3
DE_{PROG}	14.0	6.6	-	-	-	-	-	-
DE_{PTA}	23.9	6.7	-	-	-	-	-	-
REL (%)	62.0	6.1	-	-	-	-	-	-
Summer 90								
REL_{PA} (%)	42.0	2.5	41.3	2.0	40.5	2.2	40.3	2.2
REL_{SIRE} (%)	98.9	1.9	99.0	0.2	98.9	1.1	99.0	0.2
REL_{DAM} (%)	69.3	9.7	66.2	8.2	63.1	8.7	62.0	8.8
DE_{PROG}	30.1	12.6	16.1	8.3	-	-	-	-
DE_{PTA}	40.3	12.7	25.9	8.4	-	-	-	-
REL (%)	73.1	5.3	63.5	7.1	-	-	-	-
Winter 91								
REL_{PA} (%)	42.3	2.5	41.8	2.0	41.4	2.1	40.8	2.3
REL_{SIRE} (%)	98.9	1.9	99.0	0.2	98.9	1.1	99.0	0.1
REL_{DAM} (%)	70.4	9.8	68.3	8.2	66.8	8.5	64.2	9.2
DE_{PROG}	37.8	17.0	30.1	13.4	12.8	6.0	-	-
DE_{PTA}	48.1	17.2	40.2	13.5	22.7	6.2	-	-
REL (%)	76.3	5.4	72.9	5.7	60.9	6.1	-	-
Summer 91								
REL_{PA} (%)	42.8	2.5	42.4	2.1	42.3	2.1	42.0	2.2
REL_{SIRE} (%)	98.9	1.8	99.0	0.2	98.9	1.0	99.0	0.1
REL_{DAM} (%)	72.4	9.9	70.7	8.4	70.4	8.5	69.2	8.9
DE_{PROG}	47.5	26.1	43.3	22.0	31.3	10.8	16.4	7.8
DE_{PTA}	58.1	26.2	53.7	22.0	41.6	10.9	26.6	7.8
REL (%)	79.2	5.3	78.9	5.5	73.8	5.3	64.3	6.6

Table 17. Regression coefficients and R^2 of DYD protein on Summer 89 pedigree estimates for bulls grouped by date of first proof.

		Date of DYD[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	397												
PA		.63	-	.12	.55	-	.10	.54	-	.09	.57	-	.11
PI		.76	-	.09	.65	-	.07	.67	-	.07	.69	-	.08
PTA_{SIRE}		.33	-	.04	.31	-	.03	.32	-	.04	.33	-	.04
PTA_{SIRE} and PTA_{DAM}		.32	.31	.12	.30	.26	.10	.31	.25	.09	.33	.27	.11
Summer 90	379												
PA		-	-	-	.59	-	.11	.55	-	.09	.55	-	.10
PI		-	-	-	.42	-	.03	.43	-	.03	.47	-	.04
PTA_{SIRE}		-	-	-	.25	-	.02	.23	-	.02	.22	-	.02
PTA_{SIRE} and PTA_{DAM}		-	-	-	.27	.30	.11	.24	.29	.09	.23	.29	.11
Winter 91	392												
PA		-	-	-	-	-	-	.67	-	.10	.64	-	.12
PI		-	-	-	-	-	-	.80	-	.07	.80	-	.10
PTA_{SIRE}		-	-	-	-	-	-	.47	-	.07	.54	-	.12
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.47	.26	.11	.53	.21	.15
Summer 91	417												
PA		-	-	-	-	-	-	-	-	-	.48	-	.05
PI		-	-	-	-	-	-	-	-	-	.63	-	.04
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.33	-	.02
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.30	.22	.05

[a]DYD weighted by DE_{PROG}

Table 18. Regression coefficients and R^2 of PTA protein on Summer 89 pedigree estimates for bulls grouped by date of first proof.

		Date of PTA[a]											
		Winter 90			Summer 90			Winter 91			Summer 91		
First Proof	n	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2	β_1	β_2	R^2
Winter 90	397												
PA		.78	-	.42	.67	-	.25	.67	-	.21	.66	-	.21
PI		.78	-	.22	.68	-	.13	.69	-	.12	.70	-	.12
PTA_{SIRE}		.41	-	.14	.36	-	.09	.36	-	.07	.37	-	.08
PTA_{SIRE} and PTA_{DAM}		.39	.39	.42	.35	.33	.25	.35	.33	.21	.36	.32	.21
Summer 90	379												
PA		-	-	-	.76	-	.39	.68	-	.24	.63	-	.20
PI		-	-	-	.60	-	.13	.57	-	.09	.57	-	.09
PTA_{SIRE}		-	-	-	.35	-	.11	.32	-	.07	.28	-	.05
PTA_{SIRE} and PTA_{DAM}		-	-	-	.39	.38	.39	.35	.33	.24	.32	.31	.20
Winter 91	392												
PA		-	-	-	-	-	-	.84	-	.39	.69	-	.24
PI		-	-	-	-	-	-	.92	-	.24	.81	-	.18
PTA_{SIRE}		-	-	-	-	-	-	.53	-	.23	.51	-	.19
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	.52	.36	.40	.50	.25	.27
Summer 91	417												
PA		-	-	-	-	-	-	-	-	-	.68	-	.23
PI		-	-	-	-	-	-	-	-	-	.77	-	.14
PTA_{SIRE}		-	-	-	-	-	-	-	-	-	.42	-	.11
PTA_{SIRE} and PTA_{DAM}		-	-	-	-	-	-	-	-	-	.39	.31	.23

[a]PTA weighted by DE_{PTA}

Predicting first genetic merit for yield traits from different sources of pedigree estimated at various times.

Table 19 contains regression coefficients and R^2 values for predicting first DYD weighted by DE_{PROG} or first PTA weighted by DE_{PTA} for milk, fat and protein from PA, PI or PTA_{SIRE} from various AM evaluation dates. Only bulls that received their first proof in Summer 91 were used. The pedigrees used were the estimates from Summer 89 to Summer 91. This approach gave the most estimates (4) of pedigree information that were not influenced by the bulls' daughter information and one estimate (Summer 91) that was influenced by the bulls' progeny.

As the pedigree information changed over time and the time difference between the first daughter information and the pedigree estimate decreased, the R^2 for PA increased, while the R^2 for PI and PTA_{SIRE} remained relatively constant. The latter was a result of the REL of the PTA_{SIRE} and PTA_{MGS} being near one at the Summer 89 AM evaluations. Thus, the PTAs remained relatively constant for the duration of the study. However, the accuracy of the PTA_{DAM}, which is used to calculate PA, was significantly less than one in Summer 89. Over time the REL_{DAM} increased as a result of additional information. PA estimates closer to the date of the first proof were better predictors of the first DYD and PTA. The Summer 91 pedigree estimates, which were estimated simultaneously with the bulls' first proofs, show the function of the AM evaluation system bringing the pedigree estimates in line with the progeny infromation. These pedigree estimates (particularly dam's PTA) were directly influenced by the young bulls' daughter information. The regression coefficients and R^2 were very near the expected values for these paticular regressions. Additionally, the effect of the change in Summer 91 to adjust for heterogeneous within herd variance may have made the dam's evaluation more useful in predicting the genetic merit of progeny.

Table 20 contains the results of adding PTA_{DAM} to the model with PTA_{SIRE} for the regressions of first DYD or first PTA milk, fat and protein on different pedigree sources estimated at different times. All son evaluations were Summer 91 first evaluations. Again, the DYDs and PTAs were

Table 19. Regression coefficients and R^2 of DYD and PTA milk, fat and protein on pedigree for bulls with first proof in Summer 91.

	Milk n=435				Fat n=435				Protein n=417			
	DYD[a]		PTA[b]		DYD[a]		PTA[b]		DYD[c]		PTA[d]	
Pedigree estimate	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2
Summer 89												
PA	.67	.11	.77	.31	.66	.13	.75	.36	.48	.05	.68	.23
PI	.80	.07	.87	.19	.85	.10	.90	.26	.63	.04	.77	.14
PTA_{SIRE}	.43	.05	.47	.15	.44	.09	.47	.23	.33	.02	.42	.11
Winter 90												
PA	.72	.13	.82	.37	.72	.16	.81	.42	.60	.08	.77	.33
PI	.84	.07	.91	.20	.86	.11	.91	.26	.67	.04	.79	.15
PTA_{SIRE}	.46	.05	.50	.15	.45	.09	.48	.23	.35	.03	.44	.11
Summer 90												
PA	.69	.13	.78	.37	.69	.16	.78	.43	.58	.08	.74	.33
PI	.78	.07	.85	.19	.81	.10	.85	.26	.63	.04	.76	.15
PTA_{SIRE}	.43	.05	.47	.15	.42	.09	.45	.23	.34	.03	.43	.11
Winter 91												
PA	.71	.14	.79	.39	.71	.17	.78	.45	.60	.10	.74	.35
PI	.75	.07	.82	.19	.79	.11	.83	.27	.60	.04	.72	.15
PTA_{SIRE}	.41	.05	.45	.14	.42	.09	.44	.23	.33	.03	.41	.11
Summer 91												
PA	.99	.24	.99	.53	.97	.29	.97	.61	.93	.19	.97	.51
PI	.76	.07	.83	.19	.80	.11	.84	.27	.63	.04	.74	.15
PTA_{SIRE}	.41	.05	.46	.14	.42	.09	.45	.23	.34	.03	.42	.11

[a]DYD weighted by DE_{PROG}
[b]PTA weighted by DE_{PTA}
[c]DYD weighted by $DE_{PROG\_PROTEIN}$
[d]PTA weighted by $DE_{PTA\_PROTEIN}$

weighted by the DE_{PROG} and the DE_{PTA}, respectively. The R^2 values became similar to those for the respective regressions of DYD or PTA on PA. The weights for PTA_{SIRE} and PTA_{DAM} were less than .5, unless the PTA_{SIRE} and PTA_{DAM} were estimated simultaneously (Summer 91) with the first DYD or first PTA of the bull. At this time, the weight for PTA_{DAM} was greater than .5. It was as high as .6 in the case of DYD milk.

Tables 21 and 22 contain the results of regressing first evaluations in Winter 91 on each pedigree estimate prior to Winter 91 and the pedigree information estimated simultaneously with the first evaluation in Winter 91. Results were similar to those for first evaluations in Summer 91. Again there was no increase in R^2 values for PI or PTA_{SIRE} when the bulls progeny were allowed to influence the pedigree estimates in the Winter 91 AM evaluation. On the other hand, the R^2 values for the PA and for PTA_{SIRE} and PTA_{DAM} increased noticeably for the simultaneous regressions, however, the increases were generally smaller than for the simultaneous regressions in Summer 91. These results indicated the adjustment for heterogeneous variance may have only partially caused the increase in regression coefficients and R^2 values for the Summer 91 first evaluations on the Summer 91 PA and the model with PTA_{SIRE} and PTA_{DAM}. The remainder of the increase was due to influence of the young bull's progeny on the PTA_{DAM} and other sources of information that was possibly added to the dam's evaluation.

Table 20. Regression coefficients and R^2 of DYD and PTA milk, fat and protein for bulls with first proof in Summer 91 on sire PTA and dam PTA.

Date of Sire and Dam PTA	DYD[a]			PTA[b]		
	β_{SIRE}	β_{DAM}	R^2	β_{SIRE}	β_{DAM}	R^2
Milk n=435						
Summer 89	.36	.32	.11	.41	.37	.31
Winter 90	.37	.36	.13	.42	.41	.37
Summer 90	.34	.35	.13	.39	.39	.37
Winter 91	.32	.37	.14	.39	.40	.39
Summer 91	.31	.60	.25	.40	.55	.54
Fat n=435						
Summer 89	.43	.27	.14	.46	.31	.37
Winter 90	.43	.31	.16	.46	.37	.42
Summer 90	.40	.31	.16	.43	.36	.43
Winter 91	.39	.33	.18	.43	.37	.46
Summer 91	.39	.55	.30	.44	.52	.61
Protein n=417						
Summer 89	.30	.22	.05	.39	.31	.23
Winter 90	.30	.30	.08	.39	.39	.33
Summer 90	.28	.29	.08	.37	.37	.33
Winter 91	.29	.31	.10	.37	.37	.35
Summer 91	.30	.53	.20	.39	.52	.52

[a]DYD weighted by DE_{PROG}
[b]PTA weighted by DE_{PTA}

Table 21. Regression coefficients and R^2 of DYD and PTA milk, fat and protein on pedigree for bulls with first proof in Winter 91.

	Milk n = 403				Fat n = 403				Protein n = 392			
	DYD[a]		PTA[b]		DYD[a]		PTA[b]		DYD[c]		PTA[d]	
Pedigree estimate	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2
Summer 89												
PA	.47	.06	.73	.34	.51	.08	.78	.43	.67	.10	.83	.38
PI	.42	.02	.73	.18	.74	.11	.90	.33	.80	.07	.91	.24
PTA_{SIRE}	.18	.02	.35	.13	.42	.12	.48	.31	.47	.07	.52	.22
Winter 90												
PA	.53	.07	.79	.38	.59	.12	.83	.50	.75	.13	.89	.44
PI	.43	.03	.74	.18	.73	.11	.88	.33	.80	.08	.91	.24
PTA_{SIRE}	.19	.02	.36	.13	.41	.12	.48	.31	.48	.08	.53	.23
Summer 90												
PA	.57	.08	.80	.41	.60	.13	.82	.53	.76	.14	.88	.46
PI	.41	.03	.71	.18	.69	.11	.83	.33	.76	.07	.87	.24
PTA_{SIRE}	.18	.02	.35	.14	.39	.12	.45	.31	.46	.07	.51	.22
Winter 91												
PA	.79	.17	.91	.54	.76	.21	.90	.64	.96	.24	.97	.60
PI	.40	.03	.68	.18	.66	.11	.80	.33	.71	.07	.81	.24
PTA_{SIRE}	.18	.02	.33	.14	.38	.12	.43	.32	.43	.07	.48	.22

[a]DYD weighted by DE_{PROG}
[b]PTA weighted by DE_{PTA}
[c]DYD weighted by $DE_{PROG\_PROTEIN}$
[d]PTA weighted by $DE_{PTA\_PROTEIN}$

Table 22. Regression coefficients and R^2 of DYD and PTA milk, fat and protein for bulls with first proof in Winter 91 on sire PTA and dam PTA.

Date of Sire and Dam PTA	DYD[a]			PTA[b]		
	β_{SIRE}	β_{DAM}	R^2	β_{SIRE}	β_{DAM}	R^2
Milk n=403						
Summer 89	.19	.27	.06	.35	.38	.34
Winter 90	.21	.30	.07	.38	.41	.38
Summer 90	.21	.34	.09	.37	.42	.41
Winter 91	.24	.51	.19	.38	.51	.55
Fat n=403						
Summer 89	.44	.11	.13	.51	.30	.46
Winter 90	.44	.18	.15	.50	.35	.52
Summer 90	.41	.20	.15	.47	.36	.54
Winter 91	.42	.34	.22	.46	.43	.64
Protein n=392						
Summer 89	.47	.26	.11	.52	.36	.39
Winter 90	.49	.31	.13	.52	.40	.45
Summer 90	.46	.33	.14	.50	.41	.47
Winter 91	.45	.50	.24	.48	.49	.60

[a]DYD weighted by DE_{PROG}
[b]PTA weighted by DE_{PTA}

Predicting change in PTA milk of bull dams from information on son's daughters

Means and SDs for genetic parameters of bull dams and the averages of their sons grouped by the AM evaluation date the first granddaughter information appeared for each dam are in Table 23. The mean and SD for REL_{DAM} and PTA_{DAM} are in brackets [ ] for the AM evaluation each group of dams received first granddaughter information. The REL_{DAM} increased considerably at the AM evaluation the first granddaughter information was included. Mean REL_{DAM} did not approach the mean REL_{SIRE}.

Mean PTA_{DAM} decreased for each group of bull dams when first granddaughter information was received, except for the group of bull dams that received first granddaughter information in Winter 91. Mean of the $\overline{DE}_{PROG\_SONS}$ was only 13.4 for this group. Mean of the ΣDE_{PROG_SONS} of the dams was the lowest for this group of bull dams, also. Mean PTA_{DAM} of this group of dams did eventually decrease to 408 kg when the second evaluation of more accurate grandaughter information was received in Summer 91. First granddaughter information on this group of bull dams, however, was the least accurate overall. The decrease in mean PTA_{DAM} for milk suggests that the PTAs of the bull dams were biased upward. Lactation information on several granddaughters placed randomly in many herds, which results from a son or sons in an A.I. progeny test program, resulted in a more accurate estimate of the dam's true transmitting ability. The decrease in mean PTA_{DAM} in all groups from Winter 91 to Summer 91 coincided with the adjustment for heterogeneous variance.

Mean number of sons per dam when first granddaughter information was received was around 1.2 sons, with a range from 1 to 4 sons. The mean number of sons for each dam increased within each group with subsequent AM evaluations indicating multiple sons were obtained from several of the dams.

Table 23. Means and SD[1] for bull dams grouped by date of first granddaughter information.

	Date of first granddaughter information							
	Winter 90		Summer 90		Winter 91		Summer 91	
Genetic Parameter	Mean	SD	Mean	SD	Mean	SD	Mean	SD
REL_{DAM} (%)	n = 203		n = 212		n = 195		n = 197	
Summer 89	56.8	5.2	56.4	4.9	55.3	4.3	54.4	4.6
Winter 90	[61.7]	[5.1]	59.0	4.8	57.3	4.1	56.7	4.3
Summer 90	64.2	5.7	[62.8]	[4.9]	58.6	4.4	57.8	4.5
Winter 91	65.6	6.0	65.0	5.6	[62.0]	[4.5]	59.1	4.6
Summer 91	67.5	6.6	67.6	6.2	65.3	4.6	[63.7]	[4.9]
PTA_{DAM} (kg)								
Summer 89	362	276	402	255	427	268	441	260
Winter 90	[352]	[286]	401	261	429	281	448	276
Summer 90	345	283	[381]	[271]	429	292	444	287
Winter 91	363	290	384	279	[435]	[301]	460	298
Summer 91	351	274	377	264	408	281	[427]	[277]
No.sons/dam								
Winter 90	1.1	0.5	-	-	-	-	-	-
Summer 90	1.4	0.8	1.2	0.5	-	-	-	-
Winter 91	1.6	1.0	1.5	0.9	1.2	0.5	-	-
Summer 91	1.8	1.4	1.8	1.4	1.4	0.8	1.2	0.5
$\overline{DYD}_{SONS}$ (kg)								
Winter 90	397	297	-	-	-	-	-	-
Summer 90	398	304	395	318	-	-	-	-
Winter 91	442	295	440	316	501	398	-	-
Summer 91	478	233	479	278	491	312	503	366
$\overline{DE}_{PROG\_SONS}$								
Winter 90	15.2	7.7	-	-	-	-	-	-
Summer 90	32.4	14.4	15.7	9.0	-	-	-	-
Winter 91	39.2	21.6	29.6	17.7	13.4	6.8	-	-
Summer 91	49.3	26.0	42.1	30.5	31.8	11.7	17.0	8.2
ΣDE_{PROG_SONS}								
Winter 90	17.3	11.3	-	-	-	-	-	-
Summer 90	42.9	29.1	18.4	12.4	-	-	-	-
Winter 91	59.5	49.0	39.8	25.4	15.7	10.2	-	-
Summer 91	83.0	68.1	67.4	50.3	42.3	24.2	20.2	11.5
ΣDE_{PTA_SONS}								
Winter 90	28.1	15.3	-	-	-	-	-	-
Summer 90	56.5	36.6	29.7	15.5	-	-	-	-
Winter 91	75.6	57.7	54.6	32.5	26.8	13.9	-	-
Summer 91	101.8	81.3	86.2	62.8	56.1	31.7	32.0	15.3

[1]Statistic in brackets is at the time of first sons' evaluations.

The groups of dams with first granddaughter information in Winter 90 and Summer 90 had $\overline{DYD}_{SONS}$ that increased with each subsequent AM evaluation. The high mean and SD for the $\overline{DYD}_{SONS}$ for each group of dams at the first presence of granddaughter information in Winter 91 and Summer 91 coincide with the changes in the AM evaluation for the expansion of the variance to RIPs and the adjustment for heterogeneous variance.

Distributions in Table 24 were for the percentage of dams whose PTAs' change by certain levels when first granddaughter information from sons was added and the overall change in the PTA_{DAM} from Summer 89 to Summer 91 for each group. Most dams' PTAs changed from -200 to 200 kg over the evaluations included in this study. The average change tended to be negative. The Winter 91 group appeared to be the only exception to this trend. A small number of dams had substantial changes in their PTAs (± 300 to ± 600 kg), however, on average change in dam's PTA from the addition of granddaughters information from sons was small.

Table 25 contains the weighted means and SDs for the change in PTA_{DAM} (Δ PTA_{DAM}), the $\overline{DYD}_{SONS}$, the average PTA of sons - the average PA of sons ($\overline{PTA_{SONS} - PA_{SONS}}$) the average DYD of sons - the average PA of sons ($\overline{DYD_{SONS} - PA_{SONS}}$). Observations in dam's $\overline{DYD}_{SONS}$ and $\overline{DYD_{SONS} - PA_{SONS}}$ and each observation for Δ PTA_{DAM} were weighted by ΣDE_{PROG_SONS} at the respective AM evaluation of the DYD used. Observations involving $\overline{PTA_{SONS} - PA_{SONS}}$ were weighted by ΣDE_{PTA_SONS} at the respective AM evaluation of the PTA used. The diagonals for each variable contain the mean and SD from the first occurence of granddaughter information for each group of bull dams. Values below the diagonal were from the subsequent AM evaluations on these animals. The bottom row for Δ PTA_{DAM} contains the overall change in mean PTA_{DAM} for the duration of the study (Summer 89 to Summer 91). The bottom rows for $\overline{PTA_{SONS} - PA_{SONS}}$ and $\overline{DYD_{SONS} - PA_{SONS}}$ contain the mean and SD of the PA at the begining of the study (PA in Summer 89) subtracted from the final, most accurate average PTA and DYD (Summer 91) of the sons for each group of dams. PA was removed from the PTA and DYD because PA is the estimate of transmitting ability before the animal has own records or progeny information. These adjusted

Table 24. Distribution of change in dam's PTA milk (kg) by date of dam's first son information.

	Percentage of dams by date of first son information							
	Winter 90		Summer 90		Winter 91		Summer 91	
Levels (kg)	Change 1	Change 5	Change 2	Change 5	Change 3	Change 5	Change 4	Change 5
-501 to -600	-	0.5	-	-	-	-	-	-
-401 to -500	-	0.5	-	0.9	-	-	-	0.5
-301 to -400	-	1.0	-	1.4	-	1.5	0.5	1.5
-201 to -300	1.0	6.9	-	6.6	1.0	4.6	2.5	7.6
-101 to -200	12.3	14.8	9.4	15.1	6.2	18.5	15.7	16.2
-1 to -100	43.8	28.1	53.3	33.0	35.9	34.9	47.7	29.9
0 to 99	36.0	29.6	33.5	30.2	48.2	26.2	27.4	27.9
100 to 199	4.9	14.3	3.8	8.0	7.7	10.8	5.1	10.2
200 to 299	1.5	3.0	-	3.3	1.0	2.6	1.0	3.0
300 to 399	-	1.0	-	0.9	-	0.5	-	1.0
400 to 499	0.5	0.5	-	0.5	-	0.5	-	0.5
500 to 599	-	-	-	-	-	-	-	1.0
600 to 699	-	-	-	-	-	-	-	0.5

Change 1 = PTA Winter 90 - PTA Summer 89
Change 2 = PTA Summer 90 - PTA Winter 90
Change 3 = PTA Winter 91 - PTA Summer 90
Change 4 = PTA Summer 91 - PTA Winter 91
Change 5 = PTA Summer 91 - PTA Summer 89

variables were estimates of the average Mendelian sampling of the dams' sons plus the average bias in the PA.

Means on the diagonal for Δ PTA_{DAM} showed the average PTA of bull dams decreased when they received first granddaughter information. Although the average PTA of the bull dams receiving first granddaughter information in Winter 91 increased an average of 3 kg when they received their first granddaughter information, it decreased when they received their second set of granddaughter information by an average of -31 kg. The mean and SD of the first $\overline{DYD}_{SONS}$ was the second largest for this group of bull dams. The dams in this group also had the lowest means for first $\overline{DE}_{SONS}$ and ΣDE_{PROG_SONS}. The overall change in the PTA_{DAM} (Summer 89 to Summer 91) for the bull dams receiving first granddaughter information in Summer 91 was small (-2 kg). However, the change in PTA_{DAM} from AM evaluation immediately prior to the AM evaluation they received first grandaughter information (Winter 91 to Summer 91) was larger (-33 kg). This indicates the PTA_{DAM} was gradually increasing over time until the presence of granddaughter information and perhaps the adjustment for heterogeneous within herd variance in Summer 91 decreased it. The resulting negative means for $\overline{PTA_{SONS} - PA_{SONS}}$ and $\overline{DYD_{SONS} - PA_{SONS}}$ indicate that the PA overestimated the daughter performance of progeny test bulls. The expectation for this variable is zero because the PA is the only estimate of an individual's true transmitting ability before own records or progeny information is available. The bottom row of means for $\overline{PTA_{SONS} - PA_{SONS}}$, where the average PA in Summer 89 was subtracted from the average PTA of the sons in Summer 91 and weighted by ΣDE_{PTA_SONS} in Summer 91, indicate that there may not be as much bias in the PA as early estimates of the PTA of the sons indicated.

Regression coefficients and R^2 of Δ PTA_{DAM} milk weighted by ΣDE_{PTA_SONS} or ΣDE_{PROG_SONS} for separate regressions on $\overline{DYD}_{SONS}$, $\overline{DYD_{SONS} - PA_{SONS}}$ or $\overline{PTA_{SONS} - PA_{SONS}}$ are in Table 26. For each set of regressions, the diagonals contain the weights and R^2 for the first granddaughter information of each group to predict the change in PTA_{DAM} from the previous AM evaluation. The bottom row of each set of weights and R^2 indicated the ability of predicting overall change in PTA_{DAM} (Summer 89 to Summer 91) from the most recent (Summer 91) granddaughter informa-

Table 25. Means and SD for change in PTA milk and son's mean DYD - mean PA by date of first granddaughter information.

	Date of first granddaughter information							
	Winter 90		Summer 90		Winter 91		Summer 91	
Evaluation dates	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Δ PTA_{DAM}[a] (kg)	n = 203		n = 212		n = 195		n = 197	
Summer 89 to Winter 90	-12	370	-	-	-	-	-	-
Winter 90 to Summer 90	-12	451	-22	275	-	-	-	-
Summer 90 to Winter 91	16	398	-1	400	3	298	-	-
Winter 91 to Summer 91	-18	642	-9	570	-31	485	-33	394
Summer 89 to Summer 91	-24	1442	-39	1097	-20	865	-2	697
$\overline{DYD}_{SONS}$[a] (kg)								
Winter 90	374	1181	-	-	-	-	-	-
Summer 90	392	1903	395	1299	-	-	-	-
Winter 91	434	2189	440	1851	492	1468	-	-
Summer 91	473	2454	490	1964	503	1949	532	1533
$\overline{DYD_{SONS} - PA_{SONS}}$[a] (kg)								
Winter 90-Summer 89	-81	1155	-	-	-	-	-	-
Summer 90-Winter 90	-80	1713	-101	1079	-	-	-	-
Winter 91-Summer 90	-50	1799	-70	1514	-48	1433	-	-
Summer 91-Winter 91	-34	1960	-42	1616	-69	1706	-47	1398
Summer 91-Summer 89	-23	2345	-33	1818	-30	1876	6	1455
$\overline{PTA_{SONS} - PA_{SONS}}$[b] (kg)								
Winter 90-Summer 89	-63	899	-	-	-	-	-	-
Summer 90-Winter 90	-50	1037	-57	790	-	-	-	-
Winter 91-Summer 90	-23	961	-37	912	-22	795	-	-
Summer 91-Winter 91	-13	963	-20	839	-56	800	-28	806
Summer 91-Summer 89	-1	1188	-12	989	-21	920	26	887

[a]Δ PTA_{DAM}, $\overline{DYD}_{SONS}$ and $\overline{DYD_{SONS} - PA_{SONS}}$ weighted by ΣDE_{PROG_SONS}

[b]$\overline{PTA_{SONS} - PA_{SONS}}$ weighted by ΣDE_{PTA_SONS}

tion. The off-diagonals indicated weights and R^2 values for second and/or later granddaughter information to predit the change in PTA_{DAM} from the previous AM evaluation.

The R^2s for first $\overline{DYD_{SONS}}$ to predict Δ PTA_{DAM} ranged from .20 to .56, while, the range in R^2s for first $\overline{DYD_{SONS} - PA_{SONS}}$ was higher (.29 to .68). The R^2 for $\overline{PTA_{SONS} - PA_{SONS}}$ were the highest, ranging from .33 to .72. The weights for this variable ranged from .30 to .39, which were within the ranges of the weights for w_3 in Table 27 for the PTA function when the cow had 5 complete lactations and 4 or 5 progeny. The lower coefficients and R^2s on the off-diagonals indicate second or later granddaughter information does not impact the PTA_{DAM} as much as first granddaughter information. The overall change in PTA_{DAM} (Summer 89 to Summer 91) was predicted with the highest accuracy (R^2 from .47 to .59) from the Summer 91 $\overline{PTA_{SONS} - PA_{SONS}}$. These results indicate the information on granddaughter performance is influencing the PTA of bull dams and that the PTA's of bull dams before they had granddaughter information were overestimating their true transmitting abilities. Acquiring granddaughter information tended to decrease the PTA's of bull dams, perhaps bringing them closer to the true transmitting abilities.

Table 26. Regression coefficients and R^2 of dam's change in PTA milk on mean DYD of sons or mean PTA or DYD sons - mean PA[1] sons

		Date of first granddaughter information							
		Winter 90		Summer 90		Winter 91		Summer 91	
Evaluation Dates		β	R^2	β	R^2	β	R^2	β	R^2
Δ PTA_{DAM}[a]	$\overline{DYD}_{SONS}$								
Summer 89 to Winter 90	Winter 90	.14	.20	-	-	-	-	-	-
Winter 90 to Summer 90	Summer 90	.11	.22	.13	.37	-	-	-	-
Summer 90 to Winter 91	Winter 91	.07	.14	.08	.14	.15	.56	-	-
Winter 91 to Summer 91	Summer 91	.02	.004	-.01	.003	.03	.01	.13	.26
Summer 89 to Summer 91	Summer 91	.25	.19	.26	.21	.25	.31	.25	.32
Δ PTA_{DAM}[a]	$\overline{DYD_{SONS} - PA_{SONS}}$								
Summer 89 to Winter 90	Winter 90	.17	.29	-	-	-	-	-	-
Winter 90 to Summer 90	Summer 90	.16	.35	.18	.48	-	-	-	-
Summer 90 to Winter 91	Winter 91	.08	.12	.13	.23	.17	.68	-	-
Winter 91 to Summer 91	Summer 91	.14	.18	.13	.14	.11	.14	.20	.53
Summer 89 to Summer 91	Summer 91	.44	.54	.42	.48	.30	.41	.30	.40
Δ PTA_{DAM}[b]	$\overline{PTA_{SONS} - PA_{SONS}}$								
Summer 89 to Winter 90	Winter 90	.30	.33	-	-	-	-	-	-
Winter 90 to Summer 90	Summer 90	.21	.35	.31	.51	-	-	-	-
Summer 90 to Winter 91	Winter 91	.11	.13	.19	.24	.32	.72	-	-
Winter 91 to Summer 91	Summer 91	.19	.19	.20	.17	.17	.18	.39	.61
Summer 89 to Summer 91	Summer 91	.56	.59	.57	.42	.42	.47	.60	.55

[1]PA from the AM previous the DYD or PTA, except dam's change in PTA overall used the Summer 89 PA.
[a]Δ PTA_{DAM} weighted by ΣDE_{PROG_SONS}
[b]Δ PTA_{DAM} weighted by ΣDE_{PTA_SONS}

Table 27. Examples of REL and weights for w in the PTA function for various information on a cow[1]

Information available	w_1	w_2	w_3	REL (%)
PA, 3 records and no progeny	.545	.455	0	53
PA, 5 records and no progeny	.419	.581	0	55
PA, 5 records and 1 daughter	.379	.526	.095	57
PA, 5 records and 1 son	.379	.526	.095	61
PA, 5 records and 3 daughters	.319	.442	.239	59
PA, 5 records and 3 sons	.319	.442	.239	69
PA, 5 records and 5 daughters	.275	.382	.344	61
PA, 5 records and 5 sons	.275	.382	.344	74
PA, 5 records, 2 daughters and 3 sons	.275	.382	.344	70
PA, 5 records, 4 daughters and 6 sons	.205	.284	.511	77

[1]Source (VanRaden and Wiggans, 1991)

Evidence of bias or errors in dams of bulls with different recognition status as young sires.

Most A.I. organizations have certain herds designated as young sire sampling herds. The purpose of these herds is to obtain a random sample of daughters in several herds from young bulls that have no previous daughter information. When the bulls have a sufficient number of daughters with lactation records, they are evaluated on their daughters' performance. The bulls with the most desirable daughter perfomance are brought into the active line-up of the respective A.I. organization. Most bulls proven through A.I. were sampled in a limited number of designated herds. The semen distributed to each herd insured that there would be a small number of daughters per herd and a total of 40 to 60 first crop daughters. However, when an A.I. organization acquires a young sire with pedigree characteristics the respective A.I. organization considers unique (possibly based on the dam's phenotype), they offer the bull to any herd. Thus, these particular bulls usually have a larger number of first crop daughters. Most of the herds that use these particular bulls are not herds designated by the A.I. organization as young sire sampling herds. Bias or errors may be present in the pedigree estimates and/or the daughter information of these bulls that are recognized as unique and sampled heavily. Although the dams may have high PTAs, their exceptional performance may be a result of preferential treatment as well as superior genes.

Summer 91 PTAs and DYDs were used to evaluate the amount bias or errors in evaluations of dams or progeny of bulls sampled outside the designated sampling herds. Summer 89 pedigree estimates were used because they were the only AM pedigree estimates available before any of these bulls had daughter information. Table 28 contains means and SDs for milk, fat and protein genetic parameters of the 1,624 bulls (1,604 for protein) in the data with less than 100 daughters in Summer 91 compared to the 103 bulls (102 for protein) that were designated as heavily sampled bulls (offered to any herd) or had 100 or more daughters by Summer 91. All variables were weighted by DE_{PROG}, except PTA - PA was weighted by DE_{PTA}. Analysis of variance weighted by DE_{PROG} or DE_{PTA} revealed significant differences ($p < .01$) between the two groups for $\overline{DYD - PA}$ and

Table 28. Means and SD for milk, fat and protein genetic parameters comparing bulls sampled in designated herds vs. heavily sampled bulls.

	Sampled in designated herds						Heavily sampled					
	Milk[a] n = 1624		Fat[a] n = 1624		Protein[b] n = 1604		Milk[a] n = 103		Fat[a] n = 103		Protein[b] n = 102	
Genetic Parameters	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DYD - PA (kg)	6	1727	-2.1	61.6	-2.2	46.4	-107	2953	-7.5	108.1	-5.7	79.1
PTA - PA (kg)	9	1483	-1.5	53.3	-1.0	40.1	-97	2815	-6.8	103.9	-4.5	77.2
Summer 89												
PA (kg)	501	1085	18.1	41.5	14.3	28.5	560	2002	23.0	86.8	16.4	50.3
PI (kg)	385	813	12.6	30.6	11.7	20.9	402	1446	13.3	52.9	12.0	34.6
PTA_{SIRE} (kg)	594	1443	19.6	53.9	17.3	32.1	617	2582	20.7	101.3	17.6	53.9
PTA_{DAM} (kg)	408	1565	16.6	60.6	11.3	44.3	503	2823	25.3	159.8	15.3	86.5
REL_{PA} (%)	40.1	12.6	40.1	12.6	39.4	14.1	40.7	21.5	40.7	21.5	40.2	22.3
REL_{SIRE} (%)	98.9	4.1	98.9	4.1	98.9	4.6	98.9	3.3	98.9	3.3	98.9	3.2
REL_{DAM} (%)	61.3	50.6	61.3	50.6	58.5	56.4	63.8	86.5	63.8	86.5	62.1	89.7
Summer 91												
DYD (kg)	507	1831	16.1	64.7	12.1	47.9	453	2906	15.5	99.8	10.7	72.6
DE_{PROG}	43.8	99	43.8	99	41.2	93	150.1	1105	150.1	1105	148.2	1119

[a]Milk and [a]Fat weighted by DE_{PROG}, except PTA - PA weighted by DE_{PTA}

[b]Protein weighted by $DE_{PROG\_PROTEIN}$, except PTA - PA weighted by $DE_{PTA\_PROTEIN}$

$\overline{PTA - PA}$ for milk, fat and protein. Means of $\overline{DYD - PA}$ and $\overline{PTA - PA}$ for the bulls sampled in designated sampling herds were near the expected value of zero, while means of $\overline{DYD - PA}$ and $\overline{PTA - PA}$ for the heavily sampled bulls were less than zero. PA's of the latter bulls overestimated their respective PTAs and DYDs for each trait. The large SD for the heavily sampled bulls suggested that not all bulls that were heavily sampled were from dams with inflated PTAs. Less variance in PTAs than DYDs resulted in the means for PTA - PA being closer to zero than the respective means for DYD - PA, except for milk in the bulls sampled in designated herds. Means for Summer 89 pedigree estimates were consistantly higher in the heavily sampled group for all traits. Differences in the average PTA_{DAM} between the two groups were the largest discrepancies in the average pedigree estimates. Mean PTA_{DAM} for the heavily sampled bulls was 95 kg, 8.7 kg and 4.0 kg higher for milk, fat and protein, respectively. Reliabilities for PA and Sire were similar between the two groups, but REL_{DAM} was 2.5% higher for milk and fat and 3.6% higher for protein in the heavily sampled group. Mean DYDs for milk and protein in Summer 91 were higher for bulls sampled in designated herds, while mean DYDs for fat were similiar at 16.1 kg and 15.5 kg for bulls sampled in designated herds and heavily sampled bulls, respectively. The average DE_{PROG} for heavily sampled bulls was considerably higher than that of the bulls sampled in designated herds.

Evidence of bias or errors in progeny test programs of different A.I. organizations.

Table 29 contains the means and SDs of various genetic parameters for milk, fat and protein of bulls in the data by the respective A.I. organizations that sampled them. All variables were weighted by DE_{PROG}, except PTA - PA was weighted by DE_{PTA}. The nine A.I. organizations used in the study were identified by letters A to I.

The number of bulls sampled by the A.I. organizations varied from 36 to 382 bulls. Means of the A.I. organizations for PTA - PA and DYD - PA were significantly different ($p < .01$) for milk, fat and protein. The range of values for $\overline{DYD - PA}$ milk was from -81 kg to 158 kg, while, the range

Table 29. **Means and SD of milk, fat and protein pedigree information from Summer 89 and DYD from Summer 91 (kg) for each stud.**

A.I.		PTA - PA		DYD - PA		PA		PTA_{SIRE}		PTA_{DAM}	
organization	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Milk[a]											
A	62	-42	1456	-63	1663	561	1019	592	1285	528	1369
B	270	8	1506	7	1738	543	1041	630	1536	456	1527
C	256	30	1613	34	1835	425	1211	559	1508	292	1579
D	141	-13	1736	-22	1951	530	1053	623	1431	437	1468
E	179	14	1350	13	1580	500	946	573	1386	427	1453
F	97	-48	1478	-81	1759	510	1133	565	1582	454	1435
G	221	-31	1450	-51	1746	489	1012	599	1395	380	1481
H	36	126	1504	158	1679	480	1187	621	1398	338	2025
I	382	16	1390	19	1621	509	1122	586	1470	432	1604
Fat[a]											
A	62	-3.3	46.6	-4.5	53.1	21.2	35.5	20.8	44.2	21.6	59.1
B	270	-1.3	51.4	-1.7	59.9	17.8	42.7	19.7	62.9	15.8	59.8
C	256	-0.4	60.0	-0.6	68.0	16.2	39.9	18.3	48.1	14.1	66.0
D	141	-3.2	65.6	-4.1	72.9	19.7	40.7	21.5	52.8	17.8	63.3
E	179	-1.7	46.3	-2.4	53.1	17.9	38.4	16.9	53.3	19.0	57.1
F	97	-3.4	55.3	-5.1	63.9	19.5	42.9	20.3	61.0	18.7	68.0
G	221	-1.9	52.9	-2.9	63.0	19.0	38.7	20.5	47.4	17.6	53.5
H	36	1.2	59.3	1.5	65.5	14.9	43.8	15.4	65.6	14.4	62.9
I	382	-1.7	49.3	-2.2	57.1	18.8	43.7	20.2	52.5	17.6	62.5
Protein[b]											
A	62	-2.3	36.5	-3.9	41.5	16.4	24.0	17.3	26.5	15.5	38.6
B	267	-0.9	38.1	-2.3	44.1	14.5	28.1	17.4	36.2	11.6	43.7
C	256	0.0	46.2	-0.4	52.7	12.8	30.1	16.6	31.5	8.9	47.3
D	141	-2.1	45.3	-3.3	50.9	15.7	27.9	18.6	32.7	12.7	39.1
E	176	-0.8	36.1	-2.2	40.5	14.2	25.0	16.0	29.7	12.4	41.0
F	97	-2.2	39.8	-4.2	45.2	14.7	27.8	16.5	39.0	12.9	42.6
G	220	-1.8	41.4	-3.2	48.8	14.1	28.7	17.9	31.1	10.4	43.3
H	33	1.0	41.8	-0.5	45.6	12.8	27.7	15.9	31.2	9.6	50.9
I	372	-1.0	37.8	-2.4	44.1	14.7	28.5	17.4	29.3	11.9	44.3

[a]Milk and Fat observations weighted by DE_{PROG}, except PTA - PA weighted by DE_{PTA}
[b]Protein observations weighted by $DE_{PROG\_PROTEIN}$, except PTA - PA weighted by $DE_{PTA\_PROTEIN}$

for $\overline{\text{PTA} - \text{PA}}$ milk was less at -48 kg to 126 kg. The group with the largest positive values (H) had a small sample of bulls (n = 36). This group of bulls also had the largest positive value for $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ fat and the largest positive value for $\overline{\text{PTA} - \text{PA}}$ protein. The high positive results indicated the daughters of the bulls were better than the PA predicted. The expected values for $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ was zero. Thus, daughters of these bulls may have been biased upward or the PA biased downward. The negative results for $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ indicated the PA was biased upward for these groups or daughter deviations were biased downward. A.I. organization B, whose $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ for milk were nearest zero (the expected value), had the highest mean for PTA_{SIRE}, but not PTA_{DAM}. The A.I. organization (A) with the highest mean PTA_{DAM} for milk, fat and protein had the second highest mean PTA_{SIRE}. The $\overline{\text{PTA} - \text{PA}}$ and $\overline{\text{DYD} - \text{PA}}$ for this group were negative for each trait, which indicated possible upward bias in the bulls' PAs caused by the PTA_{DAM} overestimating her true transmitting ability. Means for PTA - PA and DYD - PA that deviated from zero were most likely caused by combinations of overestimated PAs and errors or biased evaluations of the daughters, rather than one effect alone.

Means for PTA - PA and DYD - PA fat were less than zero for all A.I. organizations except H. This was due to overestimation of the DYD by the PA and/or possible errors in evaluating the DYDs. High and low means varied by only 6.6 kg for DYD - PA fat and 4.6 kg for PTA - PA between all groups. The range between the high group and low group for mean DYD fat was 2.3 kg.

Means for DYD - PA protein were negative for all A.I. organizations. Means for PTA - PA protein were negative for all A.I. organizations, except C and H. Means of PTA - PA and DYD - PA deviated from zero less for protein than fat and milk. The overall range from the high group to the low group for $\overline{\text{DYD} - \text{PA}}$ was 3.8 kg for protein, while, the range for $\overline{\text{PTA} - \text{PA}}$ was 3.3 kg.

A.I. organization H had the largest positive mean for PTA - PA and DYD - PA for milk and fat. A.I. organization F had the largest negative means for PTA - PA and DYD - PA for milk, fat and protein. This group (F) had the third highest mean PTA_{DAM} and the eighth highest mean PTA_{SIRE} for milk; the third highest mean PTA_{DAM} and the fourth highest mean PTA_{SIRE} for fat; and the second highest mean PTA_{DAM} and the seventh highest mean PTA_{SIRE} for protein. Comparatively, this group had a high mean PTA_{DAM} and a low mean PTA_{SIRE} for each trait. The negative deviations from zero for the $\overline{PTA - PA}$ and $\overline{DYD - PA}$ were partially caused by an upward bias in the PTA_{DAM}. This was also the case for A.I. organization A. Their group of bulls had the second largest negative deviation from zero for $\overline{DYD - PA}$ for each trait. They had the highest mean PTA_{DAM} for each trait.

Evidence of bias or errors in bulls grouped by rank of dam's PTA.

Means and SDs comparing groups of bulls separated by rank of dam's PTA in Summer 89 are in Tables 30, 31 and 32 for milk, fat and protein, respectively. All variables were weighted by DE_{PROG}, except PTA - PA was weighted by DE_{PTA}. Means for PTA - PA and DYD - PA were significantly different ($p < .01$) for each trait between the four groups of bulls based on rank of their dam's PTA for the respective trait. Trends in the $\overline{PTA - PA}$ and $\overline{DYD - PA}$ for each trait were: the bulls with the lowest mean PTA_{DAM} had the largest positive deviations and the bulls with the highest mean PTA_{DAM} had the largest negative deviations. This indicated the bulls from the lower dams were underestimated by the PA and the bulls from the higher dams were overestimated by the PA. The range in PTA_{DAM} was larger for the lowest and highest dam groups compared to the two middle dam groups. Mean and SD for PTA_{SIRE} was similar between the groups for each trait.

Ranges for PTA_{DAM} in the groups for milk in Table 30 were: -327 to 250 kg, 250 to 422 kg, 422 to 592 kg and 593 to 1420 kg. The values for $\overline{PTA - PA}$ deviated from zero less than the values for $\overline{DYD - PA}$ due to the decreased variance of PTAs versus DYDs. The highest dam group had the largest negative deviation from zero for $\overline{PTA - PA}$ (-49 kg) and $\overline{DYD - PA}$ (-65 kg). The extremely high PTA of dams of these bulls caused the PAs to overestimate their PTAs and DYDs. The lowest dam group had the largest positive deviation from zero for $\overline{PTA - PA}$ (42 kg) and

Table 30. Means and SDs comparing groups of bulls separated by rank of PTA milk of dam in summer 89.

Genetic Parameters[a]	Range PTA_{DAM} (kg) -327 to 250 n=411 Mean	SD	Range PTA_{DAM} (kg) 250 to 422 n=411 Mean	SD	Range PTA_{DAM} (kg) 422 to 592 n=411 Mean	SD	Range PTA_{DAM} (kg) 593 to 1420 n=411 Mean	SD
DYD - PA (kg)	48	1838	33	1745	-12	1583	-65	1722
PTA - PA (kg)	42	1600	30	1503	-4	1350	-49	1474
Summer 89								
PA (kg)	334	870	463	771	551	724	680	848
PI (kg)	348	850	381	791	397	825	420	796
PTA_{SIRE} (kg)	580	1518	589	1487	598	1421	608	1465
PTA_{DAM} (kg)	89	769	337	316	503	303	753	804
REL_{PA} (%)	40.1	13.4	39.9	13.2	40.1	12.9	40.3	11.9
REL_{SIRE} (%)	98.9	2.3	98.9	6.2	98.9	3.2	98.9	3.7
REL_{DAM} (%)	61.4	53.9	60.8	52.7	61.6	51.7	62.4	47.7
Summer 91								
PTA_{DAM} (kg)	97	962	342	839	490	734	688	990
REL_{DAM} (%)	71.1	53.2	71.8	50.0	72.8	51.2	75.1	48.2
DYD (kg)	382	1953	496	1866	539	1614	615	1743
PTA (kg)	376	1608	496	1508	546	1277	633	1368
DE_{PROG}	58.2	421	52.0	270.9	44.6	107.9	44.0	122.7
REL (%)	79.5	40.9	78.9	41.1	78.1	38.4	77.8	39.0

[a]Genetic Parameters weighted by DE_{PROG}, except PTA - PA weighted by DE_{PTA}

$\overline{\text{DYD} - \text{PA}}$ (48 kg). The results for the same procedure, except the bulls were stratified by rank of sire PTA milk instead of dam, were similar. However, the negative result for the highest sire group (-25 kg for $\overline{\text{DYD} - \text{PA}}$ and -18 for $\overline{\text{PTA} - \text{PA}}$) wasn't as extreme as the highest dam group (-65 kg for $\overline{\text{DYD} - \text{PA}}$ and -49 for $\overline{\text{PTA} - \text{PA}}$).

Mean PA milk increased for each successive dam group from low to high mainly due to the differences in PTA_{DAM} between the groups. The difference in mean PA of the high dam group and the low dam group was 346 kg. The difference in mean PTA_{DAM} of the high dam group and the low dam group was 664 kg, while the difference in mean PTA_{SIRE} for the two groups was only 28 kg. The mean PIs for milk were intermediate for the groups. The difference was 72 kg between the high and low group for mean PI. Due to dividing the bulls into four equally sized groups based on the rank of their dam's PTA milk in Summer 89 the SDs for PTA_{DAM} in Summer 89 for the two extreme dam groups (-327 to 250 kg and 593 to 1420 kg) were about 2.5 times the SDs for two less extreme dam groups (250 to 422 kg and 422 to 592 kg). However, the SDs for PTA_{DAM} were similar (734 to 990 kg) between all four dam groups in Summer 91. This indicated the average PTA's of the dams in the two less extreme dam groups changed more by Summer 91 compared to the average PTA's of the dams in the two extreme groups. Means and SDs of pedigree REL in Summer 89 did not vary much between the four groups. Mean REL_{PA} ranged from 39.9 to 40.3%, while mean REL_{DAM} ranged from 60.8 to 62.4% in Summer 89. Mean REL_{SIRE} was near 100% (98.9%) for all groups. By Summer 91 the mean REL_{DAM} had increased for all groups to 71.1 to 75.1%. Each group of bulls had a similar mean REL (77.8 to 79.5%) for the Summer 91 AM evaluation.

Mean DYD and PTA in Summer 91 increased with each successive dam group from low to high. Mean PTA was higher than mean DYD for each group, except the group with PTA_{DAM} range of 250 to 422 kg milk. For this group, the mean PTA and DYD were equal at 496 kg, but the SD for PTA was lower (1508 kg vs. 1866 kg). Mean REL_{DAM} was highest for the group with the highest mean PTA_{DAM}; 62.4% and 753 kg, respectively. High RELs for these dams may have resulted from embryo transfer work that may have been conducted. Mean PTA_{DAM} increased from Summer 89 to Summer 91 for the two lower PTA_{DAM} groups, while, it decreased for the two higher groups. This indicated the bulls in the lower two groups had a positive influence on their dam's PTA, while, the bulls in the higher two groups had a negative influence on their dam's PTA when they received daughter information. The SD of PTA_{DAM} increased less from Summer 89 to Summer 91 for the two extreme bull dam groups than the other two groups indicating that the PTA's of dams within each group did not change with the same magnitude. The ranges for PTA_{DAM} in Summer 91 for bulls in each group from low to high were respectively, -434 to 590 kg, -70 to 1053 kg, 54 to 971 kg and 324 to 1269 kg. Although the PTAs of bull dams within a group changed over time from additional information, the bull dam groups ranked the same in Summer 91 as they did in Summer 89 (before they had sons with proofs).

Results for grouping bulls by rank of dam's PTA fat in Table 31 were similar as those for milk, except the mean PTA - PA and DYD - PA were negative for the second lowest rank of dam PTA fat group. The DE_{PROG} in Summer 91 between the groups were different in fat than milk. For milk the mean DE_{PROG} decreased as rank of dam increased, but for fat the mean DE_{PROG} increased as rank of dam increased. Change in mean PTA_{DAM} from Summer 89 to Summer 91 was less for fat than milk. The largest change for fat was in the highest dam group (23 to 74 kg), where the mean PTA_{DAM} decreased 4 kg from Summer 89 to Summer 91. The final ranges in PTA_{DAM} fat for the groups from low to high dam rank were: -15 to 24 kg, -8 to 42 kg, 5 to 36 kg and 10 to 60 kg. As in milk, the addition of son information tended to decrease the dam's PTA if it was extremely high prior to adding son information and tended to increase it if it was low prior to adding son information, but did not drastically change the rank of dams.

Results for grouping bulls by rank of dam's PTA protein in Table 32 were similar to those for milk and fat. Mean DYD - PA was negative for all dam groups. The means for PTA - PA and DYD - PA for the lowest dam group were closer to the expected value of zero than the other groups. The deviations from zero for the two variables got more negative as dam rank increased, indicating the bulls with higher PTA_{DAM} tended to have PAs that slightly overestimated their future PTA and DYD for protein. Change in mean PTA_{DAM} from Summer 89 to Summer 91 was less noticeable for protein than fat. The largest change for protein was in the lowest dam group (-11 to 7 kg),

Table 31. Means and SD comparing groups of bulls separated by rank of PTA fat of dam in summer 89.

Genetic Parameters[a]	Range PTA_{DAM} (kg) -11 to 11 n=411		Range PTA_{DAM} (kg) 11 to 16 n=411		Range PTA_{DAM} (kg) 16 to 23 n=411		Range PTA_{DAM} (kg) 23 to 74 n=411	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DYD - PA (kg)	0.5	59.2	-1.9	61.7	-2.5	60.6	-5.3	62.0
PTA - PA (kg)	0.5	51.8	-1.3	53.3	-1.8	51.6	-4.2	54.1
Summer 89								
PA (kg)	12.1	32.4	16.6	28.8	19.9	26.6	24.9	34.7
PI (kg)	11.5	29.0	12.3	31.9	13.2	29.7	13.1	31.6
PTA_{SIRE} (kg)	19.0	55.4	19.4	56.3	20.2	51.8	19.4	53.6
PTA_{DAM} (kg)	5.1	28.7	13.8	10.0	19.7	10.5	30.4	44.3
REL_{PA} (%)	39.9	12.8	40.1	13.6	40.1	12.1	40.4	12.9
REL_{SIRE} (%)	98.9	2.5	98.9	1.8	98.9	3.6	98.9	6.7
REL_{DAM} (%)	60.5	51.6	61.6	54.5	61.4	48.1	62.7	51.4
Summer 91								
PTA_{DAM} (kg)	5.2	37.5	13.1	33.2	18.2	29.5	26.4	46.6
REL_{DAM} (%)	70.4	50.2	72.2	51.2	73.2	48.0	75.0	52.4
DYD (kg)	12.6	62.7	14.7	63.1	17.4	65.1	19.7	62.8
PTA (kg)	12.7	52.2	15.3	51.2	17.9	53.0	20.8	52.1
DE_{PROG}	46.9	108.2	47.2	128.1	50.5	271.0	56.1	422.7
REL (%)	79.0	35.6	78.7	38.7	78.3	42.2	78.4	43.3

[a]Genetic Parameters weighted by DE_{PROG}, except PTA - PA weighted by DE_{PTA}

Table 32. Means and SD comparing groups of bulls separated by rank of PTA protein of dam in summer 89.

Genetic Parameters[a]	Range PTA_{DAM} (kg) -11 to 7 n=406 Mean	SD	Range PTA_{DAM} (kg) 7 to 12 n=406 Mean	SD	Range PTA_{DAM} (kg) 12 to 17 n=406 Mean	SD	Range PTA_{DAM} (kg) 17 to 45 n=406 Mean	SD
DYD - PA (kg)	-0.3	47.2	-1.8	45.6	-2.7	46.3	-4.5	44.9
PTA - PA (kg)	0.6	41.3	-0.6	39.0	-1.5	40.3	-2.9	38.8
Summer 89								
PA (kg)	9.3	20.6	13.3	16.2	16.0	16.7	19.4	20.7
PI (kg)	10.3	20.6	11.4	19.7	12.3	19.9	12.7	21.8
PTA_{SIRE} (kg)	16.5	32.1	17.1	30.2	17.8	31.9	17.6	34.2
PTA_{DAM} (kg)	2.1	23.6	9.4	8.8	14.3	7.8	21.2	24.5
REL_{PA} (%)	39.3	16.0	39.3	14.4	39.5	13.2	39.7	13.4
REL_{SIRE} (%)	98.9	2.2	98.9	5.6	98.9	6.6	98.9	1.7
REL_{DAM} (%)	58.2	64.5	58.3	57.4	59.0	52.7	59.7	53.4
Summer 91								
PTA_{DAM} (kg)	3.5	29.0	10.2	23.1	14.1	23.4	20.1	29.7
REL_{DAM} (%)	69.0	53.1	70.6	51.8	72.2	49.8	73.5	51.4
DYD (kg)	9.0	47.8	11.4	45.6	13.3	47.9	14.9	45.7
PTA (kg)	9.9	38.7	12.6	35.5	14.5	38.6	16.5	36.0
DE_{PROG}	44.4	98.4	49.0	272.0	57.7	429.5	40.5	104.8
REL (%)	78.3	34.6	77.8	40.8	78.2	46.3	76.7	38.2

[a]Genetic Parameters weighted by $DE_{PROG\_PROTEIN}$, except PTA - PA weighted by $DE_{PTA\_PROTEIN}$

where the mean PTA_{DAM} increased 1.4 kg from Summer 89 to Summer 91. The final ranges in PTA_{DAM} protein for the groups from low to high dam rank were: -10 to 29 kg, -0.5 to 28 kg, 3 to 31 kg and 8 to 44 kg. For protein, the addition of son information tended to change the PTA of some dams, but did not change the rank of groups of dams.

Conclusions

PA was a more accurate predictor than PI of DYD and PTA for milk, fat and protein of A.I. sampled bulls. Regression coefficients were less than one for both PA and PI, but R^2 values were higher for PA. Including dam with sire was substantially more accurate than PI for predicting future DYDs and PTAs for milk, fat and protein. This indicated that dam's genetic evaluation is more accurate under the animal model than it had been for past genetic evaluation systems. Prediction equations were not identical for all groups of bulls. Accuracy of prediction appeared to be declining erratically over traits with time. Possible causes included decreased variance in pedigree information, corrections for variance in shorter records in progress and corrections for differences in within herd variance. Evidence of higher R^2 values for PA from animal model evaluations adjusted for heterogeneous within herd variance vs. those previous the adjustment suggested the adjustment for heterogeneous variance stabilized the PTAs of dams and made them more useful measures of prediction.

Inclusion of granddaughter information at the time of first son's initial proof caused substantial change (-300 kg to 300 kg) in the PTA of some bull dams. First granddaughter information from the son(s) of the dam impacted the dam's PTA more than later granddaughter information from son(s). Net change over all dams was negative indicating that some dams had inflated PTAs. Bulls sampled heavily outside the designated sampling herds were more likely to have dams with inflated

PTAs than bulls sampled within the designated sampling herds. Dams with higher PTAs were more likely to have inflated proofs than dams with lower PTAs. Differences between A.I. organizations for mean PTA-PA and DYD-PA were found. The apparent source of the discrepancies were unknown.

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Appendix

Derivation of daughter yield deviation (DYD), adapted from VanRaden and Wiggans, (1991)

$$PTA_{anim} = w_1PA + w_2(YD/2) + w_3PC \quad [1]$$

$$PC = \frac{\Sigma q_{prog}(2PTA_{prog} - PTA_{mate})}{\Sigma q_{prog}} \quad [2]$$

Assume daughter without progeny

$$PTA_{prog} = w_{1prog}[(PTA_{anim} + PTA_{mate})/2] + w_{2prog}[(YD/2)] \quad [3]$$

Substituting [3] into [2] gives:

$$PC = \frac{\Sigma q_{prog}[2[(w_{1prog}[(PTA_{anim} + PTA_{mate})/2] + w_2(YD_{prog})/2)] - PTA_{mate}]}{\Sigma q_{prog}} \quad [4]$$

Equation [4] simplifies to:

$$PC = \frac{\Sigma q_{prog}(w_{1prog}PTA_{anim} + w_{1prog}PTA_{mate} + w_{2prog}YD_{prog} - PTA_{mate})}{\Sigma q_{prog}} \quad [5]$$

Since no progeny for daughters is assumed $w_3 = 0$, then $w_1 = 1 - w_2$ and [5] becomes:

$$PC = \frac{\Sigma q_{prog}[(1 - w_{2prog})PTA_{anim} + (1 - w_{2prog})PTA_{mate} + w_{2prog}YD_{prog} - PTA_{mate}]}{\Sigma q_{prog}} \quad [6]$$

Equation [6] simplifies to:

$$PC = PTA_{anim} + \frac{\Sigma q_{prog}w_{2prog}(-PTA_{anim} - PTA_{mate} + YD_{prog})}{\Sigma q_{prog}} \quad [7]$$

Substituting [7] into [1] gives:

$PTA_{anim} =$

$$w_1PA + w_2(YD/2) + w_3\left[PTA_{anim} + \frac{\Sigma q_{prog}w_{2prog}(-PTA_{anim} - PTA_{mate} + YD_{prog})}{\Sigma q_{prog}}\right] \quad [8]$$

Multiplying [8] out gives:

$PTA_{anim} = w_1PA + w_2(YD/2) +$

$$w_3PTA_{anim} - \frac{w_3\Sigma q_{prog}w_{2prog}PTA_{anim} - w_3\Sigma q_{prog}w_{2prog}PTA_{mate} + w_3\Sigma q_{prog}w_{2prog}YD_{prog}}{\Sigma q_{prog}} \quad [9]$$

Equation [9] simplifies to:

$$PTA_{anim} = x_1PA + x_2(YD/2) + x_3\left[\frac{\Sigma q_{prog}w_{2prog}(YD_{prog} - PTA_{mate})}{\Sigma q_{prog}w_{2prog}}\right] \quad [10]$$

The term mutiplied by w_3 in [10] is the DYD

$$DYD = \frac{\Sigma q_{prog} w_{2prog} (YD_{prog} - PTA_{mate})}{\Sigma q_{prog} w_{2prog}}$$

Abbreviation key:

PTA = Predicted Transmitting Ability

PA = Parent Average

YD = Yield Deviation

PC = Progeny Contribution

DYD = Daughter Yield Deviation

Vita

David J. Samuelson was born March 16, 1967 and raised on his family's dairy farm near Cannon Falls, Minnesota. He graduated from the local high school in 1985 and attended the University of Minnesota from September, 1985 to December, 1989. He graduated with a Bachelor of Science in Animal Science. In January 1990 he enrolled at Virginia Tech to pursue a Master of Science in Dairy Science. He fulfilled the degree reguirements on March 6, 1992. Publications by the author include:

Samuelson, D.J., R.E. Pearson, and B.G. Cassell. 1991. Accuracy of predicting daughter yield deviation milk from animal model information on relatives for A.I. sampled bulls. J. Dairy Sci. 74(Suppl. 1):265(Abst.).

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