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EFFECTIVENESS OF ALTERNATIVE BREEDING SCHEMES FOR A DAIRY CATTLE POPULATION OF LIMITED SIZE

By

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ABSTRACT

EFFECTIVENESS OF ALTERNATIVE BREEDING SCHEMES
FOR A DAIRY CATTLE POPULATION OF LIMITED SIZE

BY

Chu-li Chang

There are many dairy cattle populations of approximately 100,000 cows in size in the world that have sought genetic improvement. The geographically isolated dairy cattle population in Taiwan was used to demonstrate alternative breeding schemes for their rates of genetic improvement in production and their economical efficiency. Since the source of germplasm import was from the U.S., the first study was to estimate genetic responses in individual traits, yield merit functions, and total merit functions when selection was based on criteria that were currently available to the U.S. dairy cattle breeders.

To maximize genetic improvement in milk yield, several practical breeding schemes were designed in the second study. Each of the alternative breeding schemes focused on the generation of genetically superior bulls that are to be use to breed cows in the population, and each involved the use of semen imported from the U.S. These breeding schemes belonged to three categories. The first had breeding bulls produced by using local genetic resources but their sires were foreign. The second used imported germplasms to produce breeding bulls, which would not go through progeny test. The third category included each of the schemes in the first two categories plus a supplement

of additional imported germplasms. Ranking of cumulated genetic progress after 25 years showed that the best breeding scheme was the one which used imported embryos to produce bulls that would be screened by the performance of their paternal-half-sibs before used for artificial insemination purposes. This scheme included a supplement of 5% imported pregnant heifers.

Economic efficiency of the same breeding schemes was assessed in the third study, since in practice, a mere consideration of their ability to maximize genetic progress would be insufficient. In this study, the appropriate governmental agencies would be expected to bear all costs for the infrastructure and operation of a breeding scheme. Therefore, the cost factors of a scheme would include only those that would incur to farmers such as costs of semen, artificial insemination, importing heifers, and the increased costs of feeds and health and fertility problems due to increased milk production. The economic efficiency of a breeding scheme was calculated as Net Present Value of accumulated benefit over a 25 years time horizon. The ranking of schemes by economic efficiency was different from that by rate of genetic progress. However, the exact same breeding scheme was deemed to be the best according to both criteria.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

There are many dairy cattle populations of limited size in the world that operate independently, either geographically or politically. The number of cows in these limited size populations is varied. But a typical size of the population is about 100,000 cows. Each population has their own unique features in management system, feeds and feeding, and climatic conditions that would influence the level of milk production. Each population also has made efforts to improve the efficiency of milk production by breeding, feeding, and health care. In order to improve milk yield by selective breeding, much money has been spent to import germplasm. The dairy cattle population of 100,000 cows in Taiwan is a typical such population with a breeding scheme currently has 20% of cows bred by local untested AI bulls, 20% bred by natural service bulls and 60% bred by foreign semen.

The primary breeding goal for dairy producers is to improve milk yield. Other traits such as fat and protein yields, type final score, linear functional type traits, somatic cell count, calving ease, and productive life may be also important depending on breeding goals. Any of these traits must first be recorded so to have animals recorded and their relatives genetically evaluated before it can be considered in breeding goals. For the goal of increase profitability and efficiency of a cow, a joint selection on a collection of traits should be considered. However, which traits would be included with yield traits in selection program and how much each trait should be emphasized are debatable issues in every dairy breeding industry. The relative importance given to these traits was different from breeder to breeder and done in different manners.

More than 30 selection criteria are available from USDA and from Holstein Association, USA. Among these criteria, there are three kinds of criteria for genetic selection: (1) PTA (Predicted Transmitting Ability) values for selecting a trait of particular interest, (2) Product Value Indexes, and (3) Total Merit Indexes. For single trait selection, PTA value could be used as selection criterion. If producers prefer to seek improvement in several traits simultaneously, Product Value Index and Total Merit Index are available. These selection criteria were developed for various selection objectives and management conditions from farm to farm. Information on genetic responses or correlated genetic responses of all economic traits and indexed merits to various selection criteria were limited. All of these responses were useful to the breeders as a guide to set up their breeding program, and to the AI organization in choosing bulls' dam and in sampling young bulls. It is important to understand the genetic responses and correlated genetic responses in single traits and merits, when selection was based on a variety of criteria that were currently available to the U.S. dairy cattle breeders.

There is a variety of breeding schemes taken by dairy developed countries, resulting in large genetic progress in production levels. A breeding scheme is a practice of genetic selection with application of certain reproductive technology or biotechnology. The goal of selection is to allow animals with high breeding values to be parents of the next generation. The first and most important reproductive technology that had applied to breeding scheme in dairy cattle is Artificial Insemination (AI) with frozen semen. Artificial Insemination and Progeny Testing (AIPT) have been the backbone of dairy cattle improvement in developed dairy countries, and can result in rates of genetic gain of 2 to 3%/yr (Van Vleck, 1986). Embryo transfer (ET) technology enables females to have increased family sizes and shortened the generation intervals. The use of Multiple Ovulation and Embryo Transfer (MOET) in a nucleus to produce bulls for genetic improvement of dairy cattle herd could reduce generation interval and increase genetic gain by 4 to 5 % which would be superior to those achieved in conventional breeding schemes (Dekkers and Shook, 1990). Other technologies applied to breeding schemes such as large factorial mating breeding designs with use of in vitro embryo production (IVEP) and the use of genetic marker as aids to select animals which was called Marker Assisted Selection (MAS) is also studied by several geneticists. (Brascamp et al.,1993; Kashi et al., 1990; Mackinnon and Georges, 1997; Ruane and Clooeau, 1996; Spelman and Gairick, 1997).

To bring genetic material of superior merit from a foreign population into a local population is one rapid way to make genetic progress. Germplasms imported can include young bulls, pregnant heifers, frozen semen, and frozen embryos.

Most of the populations of limited size are developing populations, which have not applied the breeding schemes used in developed countries because environment conditions and biological and economical resources are not the same. Theoretical effectiveness of a breeding scheme in its rate of improvement is altered in practice due to economics and success rate of the reproduction technology involved. Many studies evaluated the cost effectiveness of breeding schemes (Hill, 1971; Dekkers and Shook. 1990).

At present time, Taiwan has a fairly well developed breeding and recording infrastructure in place; i.e. technologies such as AI, embryo transfer and DHI. The dairy cow population approximates 100,000 in size which will likely stay at the same considering the environment and resources for dairy farming. Yet, there does not exist a long-term breeding policy for the dairy population, which would accelerate genetic progress in milk yield efficiently both biologically and economically. The dairy population in Taiwan of 100,000-cow-population will be used as target population.

The overall goal of this work is to identify a breeding scheme that is optimum in both the rate of genetic progress in milk production and the economic efficiency of application. The specific objectives of this thesis were:

(1). To calculate the expected genetic responses in individual traits and indexed merits from selection based on selection criteria currently available in the U.S. This was done because all designed breeding schemes involved U.S.-imported germplasms.

(2) To design alternative breeding schemes that can be applied realistically in the target population, and to compare their expected rate of genetic progress.

(3) To compare the same schemes for their economic efficiency with respect to the conditions and biological and economical resources in application.

CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

The dairy population around the world is decreasing in size. This fact means the dairy producers must become as efficient and as profit-minded as possible. There are many dairy cattle populations of limited size in the world that operate independently, either geographically or politically. The number of cows in these limited size populations might be varied. But a typical size is about 100,000 cows. Each population has own unique features such as management system, feeds and feeding, and climatic conditions that would influence the level of milk production. Each population also has made efforts to improve the efficiency of milk production by breeding, feeding, and health care. The primary breeding goal has been to improve milk yield and has spent much money to import foreign germplasm to improve milk yield. The geographically isolated dairy cattle population of 100,000 cows in Taiwan is a typical limited size population.

The main goal of a dairy producer's genetic improvement program should be to produce replacement cows with the greatest possible genetic capability for making a profit. Fulfilling this goal requires strong, healthy cows that produce high levels of milk of desirable composition. Also, these cows must be able to stand the stress of high production through many lactation with a minimum of special care.

To set up breeding goals, traits for improvement should be set up. Can these and other traits be selected for or not depending entirely on if they are recorded and genetically evaluated. Single-trait or multi-traits selection would result in correlated responses for traits with genetic associations. Because correlated response may have economic consequence, the impact of selection for milk on the total economic merit of cows should be monitored. It is useful for the breeders and producers to know all of these responses as a guide to set up breeding program.

A breeding scheme is a practice of genetic selection with the application of specific reproductive technology or biotechnology. The goal of selection is to allow animals with high breeding values to be parents of the next generation. Artificial Insemination and Progeny Testing (AIPT) have been the backbone of dairy cattle breeding scheme in the developed dairy countries. Other reproductive and biotechnology's applied to breeding schemes, such as large factorial mating breeding designs with use of in vitro embryo production (IVEP) and the use of genetic markers as aids to select animals which was called Marker Assisted Selection (MAS), have also been studying by several geneticists. To bring in genetic material with higher genetic merit into a local population is another way to make genetic improvement especially when the foreign population is genetically superior to the local population.

Breeding schemes involve different costs, both in the initial capital and in annual running expenditure. The monetary returns from genetic improvement accumulate over a long period of time, and the pattern of returns may be erratic in early years. It is necessary to know the returns and costs for any breeding schemes so that sound investment decisions can be made.

The purpose of this chapter was to review the literature regarding the responses in various genetic merits from several known selection criteria, evaluation system to establish selection criteria, and the dairy cattle breeding strategies in the developed countries. Then, in the following chapters, several breeding schemes would be designed in order to seek an optimum breeding strategy for the specific conditions and resources in Taiwan.

TRAITS AND MERITS FOR GENETIC IMPROVEMENT

Sale of milk is the major source of income for most dairy producers. Milk yield, therefore, should receive heavy emphasis in selection programs. Other traits such as stress resistant traits (rear leg set), fertility trait (rump angular), and mastitis resistance (SCS) are also important. These traits are associated with profitability and efficiency of a dairy cow as well as the producer's net return.

Yield of milk and milk components

The largest single source of costs in milk production is management overhead costs of keeping a cow. The more milk a cow produces, the more these overhead costs are spread out and the less the cost per kilogram milk is produced. Thus, the number of cows with high genetic potential for milk yield should be maximized. With continued breeding for higher genetic output, a farmer will produce the same milk with fewer cows and at substantial saving in costs.

Yet, farmers get paid for milk volume with an adjustment for fat and protein percentage. This misleads some farmers to focus their attention on fat and protein percentage. In fact, farmers get the payment from price for the milk volume excluding the fat and protein yield and from the kilograms of fat and protein they produce. So the payment system is also really aimed at fat and protein yield. If selection is on fat percentage or protein percentage, it will actually tend to decrease milk production because the genetic correlation between fat percentage, protein percentage and milk yield is negative. So, to maximize farmers' income from milk production, select sires for improving herd should be high genetic evaluations for yield traits, not for fat and protein percentage.

Body conformation traits

Type traits have long been considered a relatively important trait of dairy cattle. In the early days of dairy cattle breeding, a cow's outward appearance (type final score) was probably the best indicator of her producing ability. Extreme dairy character, capacious barrel, and good udder were suggestive of high production. Other type traits were considered important because of their perceived positive relationship with longevity. Cows with a strong front end, that were wide, a little slope rump, with structurally sound feet and legs, and well-attached udder were seemingly more trouble-free could be recorded early in a cow's lifetime, they have some value for predicting herd life.

Many dairy producers think that single-trait selection for milk may be detrimental to cows, particularly for traits related to strength, stamina, and survival. Numerous studies (Everett et al., 1976; Foster et al., 1988; Norman and Van Vleck, 1972; Sieber et al., 1987) had investigated relationships of milk yield and conformation. Genetic correlation of milk yield and final score was near 0.1. For individual type traits, dairy character has consistently had favorable relationships with milk yield (Foster et al., 1988; Norman and Van Vleck, 1972). Udder depth has been negatively associated with milk yield (Foster et al 1988). Some studies (Foster et al. 1988, Sieber et al., 1987) found unfavorable relationships between milk yield and udder attachments. Estimates of genetic correlation of milk yield with most other type traits have usually suggested little meaningful association. Meland et al. (1982) reported no clear relationship of milk yield and type when milk selection and control lines were compared.

Health

1. Mastitis and Somatic cell counts

Somatic cell counts (SCC) from a day's milk are the best indicator of the extent to which the gland is involved in fighting a mastitis infection. The DHI program provides a monthly SCC which identifies those cows with high SCC, which might be sub-clinical mastitis. Sub-clinical milk appears to be normal. Yet, milk yield is depressing, and composition may be altered. Sub-clinical mastitis may become clinical. Genetic correlations between SCC and mastitis are moderately high (Emanuelson et al., 1988). An SCS is a $\log_2$ transformation of somatic cell count and is related to mastitis incidence. The transformation makes the values nearly normally distributed and has the simple interpretation that each increase of 1 is a doubling of the somatic cell count. As with yield, lactation averages for up to the first five lactations are included. Somatic cell score (SCS) evaluations were implemented in 1994 in the United States (Schutz, 1994). SCS evaluations are centered on breed average, which is 3.2 for Holsteins. Strandberg and Shook (1989) demonstrated that selection to reduce the rate of increase in mastitis that accompanies selection for milk yield could be economically prudent. Rogers et al (1991) suggested an index that combines linear type traits with production and SCC.

2. Reproduction

Calving ease (CE) is of economic important trait in dairy cattle and should be considered in breeding programs. Dystocia is a reproductive problem of dairy cows, especially for first-calf heifers. The economic costs of dystocia include loss of calf, veterinary fees, farmer labor costs, increased risk of subsequent health and fertility problems, increased culling, and reduced production. Factors affecting calving ease can be separated into maternal and fetal (or direct) components. Maternal calving ease (MCE) refers to characteristics of the dam giving birth (e.g., pelvic dimensions). Direct calving ease (DCE) refers to characteristics of the calf (e.g., calf size) (Meijering, 1984).

Although dystocia can be reduced by proper management procedures, such as heifer rearing and feeding during gestation, selection and breeding strategies have been identified as important additional tools to reduce dystocia in the short and long term (Meijering, 1984). Many studies have identified small but significant genetic components to both DCE and MCE; heritabilities ranged from .03 to .20 (Cue and Hayes, 1985, Meijerin, 1984; Weller and Gianola, 1989.). Genetic correlations between CE and production traits was close to zero (Meijering, 1984). Significant genetic relationships between MCE and conformation traits had been found, especially conformation traits associated with pelvic shape and pelvic dimension (Dadati. et al., 1985).

The National Association of Animal Breeders funds the analysis of calving difficulty. Using a categorical model (Berger, 1994), calving ease evaluations are calculated for bulls at Iowa State University. Evaluations are reported as the expected percentage of difficult births for first-calf heifers giving birth to a bull calf during the winter. These evaluations have been particularly helpful in promoting the use of Al dairy bulls with virgin heifers.

Reproductive performance is one of the major factors influencing the profitability of a dairy herd. Reproductive performance affects the amount of milk, breeding costs, rates of voluntary and involuntary culling, and the rate of genetic progress for traits of economic importance. Reproductive efficiency of bulls is usually measured by non-return rate, which is commonly defined as the proportion of cows that were inseminated and did not return for another service within a specified number of days, such as 28 or 56 days or commonly 60 to 90 days. The non-return rates can be used to derive useful measures of the reproductive efficiency of a bull (Koops et al., 1995).

Longevity

. Longevity has been defined in many ways. Ducrocq et al (1988) discussed two definitions of PL. True PL characterized the aptitude for a cow to remain in the herd given the management's criteria for selection and culling. Functional PL represented the ability to delay involuntary culling. Genetic selection for increased PL is expected to result in improved general health, production, and reproduction. They can increase dairy farm profitability by decreasing the number of replacement heifers needed, by allowing rearing costs to be dispersed over a longer period, and by increasing the number of cows producing at a mature level (Allaire and Gibson.,1992; Rogers et al., 1989).

Productive life (PL) (VanRaden and Klaaskate, 1993) in the United States is defined as the number of months in milk (with a maximum of 10 months per lactation) until the cow is 84 months old. PL evaluations are the same as for yield evaluations (VanRaden and Wiggans, 1995). To add accuracy for bulls, information on PL from type traits is added (Weigel et al.,1996). The Holstein Association USA combines evaluations for PL, milk and fat yields, and linear type traits to calculate an approximate multi-trait evaluation. This enhancement currently is applied only for Holstein bulls and has its greatest benefit for bulls with a type evaluation but that have a yield evaluation that is based on daughters that are too young to contribute PL information.

GENETIC EVALUATION

Advances in computing power and reduction in cost per unit of computing resource had made possible continuous improvement in evaluation system. Computers have allowed more and more complete models and statistical procedures to be used for sire and cow evaluations (Lee et al., 1985). Improvement in genetic evaluation system to accurately rank animals for selection is the most important practice in dairy cattle breeding. Accuracy of identifying superior sires and dams relies on best-unbiased prediction of breeding values. Genetic evaluation system has been frequently modified to get best-unbiased prediction of breeding values, exploiting advances in computer technology and evaluation methodology.

Current USDA animal model

The current USDA animal model can be represented as:

$$\mathbf{y} = \mathbf{Mm} + \mathbf{Za} + \mathbf{ZA_g g} + \mathbf{P_p} + \mathbf{C_c} + \mathbf{e}$$

Where **y** represents standardized milk, fat, or protein yield. **m, a, g, p,** and **C** are vectors of effects for management group, random portion of additive genetic merit, unknown-parent group, permanent environment, and herd-sire interaction, respectively. **M, Z,** $\mathbf{ZA_g}$ **P** and **C** are incidence matrices for these effects; and **e** is error. Predicted Transmitting Ability (PTA) is the estimate of genetic superiority for bulls and cows by using animal model (VanRaden and Wiggans, 1991).

The current animal model, which was implemented in 1989, has been modified frequently to meet the needs of the U.S. dairy industry and to exploit advances in computer technology and evaluation methodology. The predicted transmitting ability (PTA) reported to the dairy industry is half the animal's breeding value.

Genetic evaluations of linear type traits for Holsteins are calculated by the Holstein Association USA. A multi-trait animal model (Misztal et al., 1993) is applied with adjustment for heterogeneous variances (Weigel and Lawlor, 1994). A canonical transformation is used to create uncorrelated traits for analysis. Because the data include more than one scoring per cow, a permanent environmental effect is included.

Misztal and Wiggans (1988) obtained more precise measures of the accuracy of individual evaluations using an iterative procedure that was computationally affordable but lacked easy interpretation. Methods to summarize accuracy of PTA provided by the additional sources of information included in evaluations also were needed. The total amount of information provided by records of the animal and all its relatives is summarized by REL (Reliability) through a simple function of total DE (Daughter Equivalent) from parents, own yield, and progeny adjusted for mates. A DE is the amount of information about a parent's genetic merit available from a single lactation of a single daughter in a herd. Daughter equivalents can be converted to Reliability of a PTA for milk using the formula $REL = n / (n + 14)$ where n is the number of daughter equivalents. REL ranges from 0 (least accurate) to 99 (most accurate).

In practice, REL for females seldom exceed 80 percent. For most bulls, milk, fat, and protein will have the highest reliabilities because more daughters have performance records on those traits. Reliabilities for type traits tend to be lower since not all daughters are scored. Heritability affects reliability and, as a result, different type traits have different reliabilities. Low heritability will cause somatic cell score (SCS) reliabilities to be lower than for milk, even if all daughters have SCS data. Heritability of productive life (PL) is the lowest of all traits with PTA's calculated on a national basis. Heritability is less than 10% for PL expressed in mature daughters and less than 5% when predicted from type data on young cows (VanRaden and Wiggans,1991; Schutz, 1994).

INTERBULL

Due to increasing trade in semen, embryos and livestock in the world, breeders want to make accurate and fair comparisons between animals performing both within and across countries. One way to compare the evaluation between two countries are conversion equations. But they were used on the scales of both countries for a number of bulls and permitted estimates of genetic merit from one country to be expressed on the genetic scale of another country. Conversion equations were calculated only between pairs of countries and force all converted evaluations to be on the prediction line. Because converted evaluations were re-scaled original evaluations, bulls with converted evaluations were not re-ranked on the new scale (Wiggans et al.,1992).

Because of differences in genetic evaluation methods, differences in genetic base, differences in breeding goals, and differences in environment among countries, it is difficult to compare genetic merit evaluated by each country. An organization called INTERBULL Center was established in 1991, under contract with the Swedish University of Agricultural Sciences in Uppsala, Sweden. INTERBULL coordinated international communication. They provided international leadership in researching and developed methods for generating international genetic evaluations. Currently, the International Genetic Evaluation Service provided by INTERBULL evaluates sires from over 20 countries for three milk production traits - fat, protein and milk yield. Other traits such as health and fitness traits, including SCS and productive life will be included in the future.

INTERBULL uses a scientifically advanced method known as Multiple Across Country Evaluation (MACE) to calculate International Genetic Evaluations. MACE combines information from each country using all known relationships between animals, both within and across populations. It accounts for the possibility of animals re-ranking between certain countries. This occurs when animals perform better in certain environments than they do in others. Genetic merits are expressed in different ways and units. Legitimate units are pounds of PTA for the United States, kilograms of PTA for the United Kingdom, Ireland, and Israel, relative breeding values for Scandinavian countries, and kilograms of EBV for all other countries that participate in INTERBULL evaluations.

In 1997, INTERBULL had 34 member countries, with more likely to join in the future. 54,000 Holstein Friesian sires from around the world received international genetic evaluations expressed in PTA lbs. on the US base, in EBV kg on the Dutch base, in EBV kg on the French base and so on. A bull with an EBV for milk of 1000 kg has an EBV of 2200 pounds would be improper and unethical. Updated evaluations from INTERBULL are made available in February and August on release This provides the advantage of individual countries being able to identify those animals from around the world which will perform best under their own unique farming conditions (Banos and Sigurdsson. 1996). The Center will increase the frequency of its evaluations to four per year to match the evaluation schedules of many of the major participating countries. Now, INTERBULL and most national evaluations are calculated four times each year.

Although the equations will change with each subsequent evaluation, the changes usually are expected to be small. However, when a country changes the definition of its genetic base population, as occurs with the first evaluation of each year in Canada and with the mid-year evaluation in France, knowing the evaluation date becomes even more important because changes in conversion equations can be quite dramatic when bases change.

The best option always is to use the national or INTERBULL evaluations on a single scale. The preferred way to compare the genetic merit of bulls from different countries is to have the evaluations all expressed on the same scale. Fortunately, most bulls of interest have International Bull Evaluation Service evaluations for milk, fat, and protein yields. The file of official evaluations on the U.S. scale is available from the Animal Improvement Programs Laboratory's (AIPL's) Internet web site. The conversion equations are to convert from one scale to another for bulls without INTERBULL evaluations for milk, fat, and protein yields. There are conversion equations developed by INTERBULL to convert evaluations from other countries' scales to an U.S. basis. They are available at the AIPL web site. For example, a bull that has a Netherlands estimated breeding value (EBV) of 1700 kg for milk yield would be expected to be similar to an U.S. PTA of about 2000 pounds. This conversion is only approximate the actual PTA milk from INTERBULL. The conversion equations are directional, which means they only can approximate an U.S. PTA from an EBV from other countries, but they are not valid for estimating EBV's of other countries from an U.S. PTA or from EBV from other countries.

Current selection criteria

1. Current selection criteria for single-trait in U.S.

PTA (Predicted Transmitting Ability) could be used as selection criteria for single-traits of interest including milk, protein, fat, type traits, SCS and PL in dairy cattle. The use of PTA's have two purposes: to rank animals for genetic merit and to estimate genetic differences between animals. A cow with a PTA of 1500 for milk is expected to produce daughters averaging 500 lbs. / lactation higher production as mature cows than daughters of a cow with a PTA of 1000. The cow with a 1500 lb. PTA would rank higher than the cow with the PTA of 1000 lb. Only animals of the same breed can be compared.

For single trait selection, PTA value (Predicted Transmitting Ability) could be used as selection criterion. This value has been available for many traits of interest for genetic selection. Some breeders apply selection pressure on only one trait.

PTA for Somatic Cell Scores (SCS) were published since 1993 in the US. The heritability of SCS is approximately 9 percent. It will be more difficult to improve the SCS of the herd through selection than to improve milk production. The major way to alter the Somatic Cell Count of a herd is through management changes, not through genetic selection. If one selects on SCS, sires should be selected first on production traits and then sires that have above average SCS PTAs should be eliminated. In other words, use PTA SCS as a culling criterion once production yields meet requirement. This procedure does not decrease emphasis on production traits and will still let a producer use a group of low SCS sires.

2. Current selection criteria for multiple traits in U.S.

(1). Production or yield indices

MF$ = $.10170(PTA M)+$.58(PTA F)

= 5(PTA M/625)+1(PTA F/22)

Relative emphasis on component traits 5: 1

MFP$ = $0.031 (PTA M)+$0.8 (PTA F)+$ 2.00 (PTA P)

= 2.67(PTA M/625)+1(PTAF/22)+1.7(PTA P/19)

Relative emphasis on component traits 3 : 1 : 2

CY$ = -$.00220 (PTA M)+$1.98(PTA F)+$1.716(PTA P)

= -(PTA M/625)+32(PTAF/22)+24(PTA p/19)

Relative emphasis on component trait -1: 32 : 24

(Cheese market for Ayrshires, BS, Hs, MSs and R&Ws)

MF$, MFP$, CY$ are Product Value Indexes.

(2). Total merit indices

NM$ = 0.7(MFP$)+$11.30 (PTA PL)-$28.22 (PTA SCS-3.2)

= 10 (PTA MFP$/71)+4(PTA PL/13.2)-1(PTA SCC/1.9)

Relative emphasis on component traits 10: 4: -1

(USDA-DHIA Active AI bull evaluation.1995).

TPI = [$7.89(PTA P)+$2.22(PTA F)+$71.43(PTA T) +$12.18(UD)+

$6.5(FU) +$6.5(TP)+$6.5(RUH)+$4.87(RUW)+$4.06(UC)

= [3(PTAP/19.0)+1(PTAF/22.5)+1(PTAT/. 7)+. 65(UDC/. 8)

+. 35(FLC/. 85)] 50+576

Relative emphasis on component traits 3: 1: 1: 1:65: .35

Where .UDC=. 30(UD)+. 16(FU)+. 16(TP)+. 16 (RUH)+. 12(RUW)+ .10(UC)

Relative emphasis on component traits .3: .16:16: .16: .12: .1

FLC=. 5(Linear traits of foot and leg)+ .5(Feet and Leg Score)

Relative emphasis on component traits 1: 1

Linear traits of foot and leg = . 48(FA)+. 37(RLRV)-. 15(RLSV)

(Holstein Association, 1999)

Originally, these indexes were derived based on the current milk pricing system. In 1994, standard milk price was $.12/lb of milk, reflecting a $12.00/cwt price for milk containing 3.5 percent fat and 3.2 percent protein. The above formula is specific for Holsteins because 3.2 is the breed average SCS for Holsteins However, the price paid for milk components is expected to change as consumer demand changes over time. If profit is considered as the long-term objective, it is then important to consider selection indexes using future milk-pricing system because breeding decisions are made approximately 3 yr. before the eventual replacements begin to milk.

The TPI includes type traits that impact profitability of the animal. This index heavily emphasizes PTA protein with no direct weight on PTA milk. However, selection for fat and protein yields tends to increase milk yield as well.

BREEDING STRATEGIES

A breeding scheme is a practice of genetic selection with application of certain reproductive technology or biotechnology. To design breeding strategy is to develop strategy with respect to selection, mating, and population structure that optimize the relationships among these factors such that genetic improvement was maximized or optimized.

Artificial Insemination

(1) Progeny Testing

The Artificial Insemination and Progeny Testing (AIPT) scheme identifies bulls with superior genetic merit for milk, fat, protein and type through their relatives and many daughters' performance. In progeny testing, the young bulls are usually chosen on pedigree information for production and type and on their own conformation. Then each young test bull was mated to a number of cows; a number large enough to ensure that each bull had a sufficient number of daughters for a reliable proof. A sampling procedure is to identify those bulls receiving a favorable sample of alleles from parent.

After young bulls sampling, one method is to lay off the young bulls while waiting for their proofs (the lay-off policy). During the lay-off period, little semen was collected regularly, frozen and stored. When the proofs become available, low proof bulls were culled along with any semen which had been stored and the selected bulls were placed in the proven stud for regular service (Hinks, 1970). The second method is the collect & slaughter policy. Large amounts of semen were stored from testing bulls which wee slaughtered. When proofs were available, semen from the undesirable bulls was disposed (Johannsson, 1970). The two methods gave different rates of genetic progress and differed in running costs. The cost of storing the required volume of semen for approximately four years amounted to only about 25% of that of keeping the bulls for six years while waiting for their progeny test results (Johannsson, 1970).

Progeny testing schemes were expensive to run especially for small size population.

Progeny testing scheme required that good infrastructure be in place; i.e. good road services, a milk recording scheme, an registry system, Al services etc. Fewson (1989) demonstrated that economic benefits of testing might be low for small populations. He calculated profits of progeny testing for different population sizes. The profits for a large population (500,000) were almost the same as those for the medium population (100,000 cows) and those for the small population (20,000) were almost half those of the large population. Hunt et al (1974) found that for a population size of 115,000 cows, the progeny group sizes gave the highest annual genetic gains when 50% of the cow population was milk recorded and 40% of the tested population were bred to young bulls. The additional benefit of increasing the progeny group size from 20 to 30 daughters per bull was very small. Lindhe (1968) found that the accuracy of progeny testing increases only slightly if the size of the progeny groups exceeded 60 daughters.

(2) Selection of dairy bulls on half-sib records

Selection on the basis of half-sib performance has the disadvantage that the correlation between the average of half-sibs and the breeding value of the candidate was only half the correlation between the average of the progeny and the breeding value of the candidate. But the advantage was that the age of bulls at selection was reduced by 2 years (approximately by one-third). Owen (1989) described a half-sister selection of young bulls scheme as an alternative to the progeny testing for the genetic improvement of milk yield in a large population of dairy cows. The results indicate that the half-sib testing scheme would lead to an eventual rate of genetic progress very similar to the progeny test scheme. However, the annual cost of the half-sib testing scheme was less than a progeny test scheme, because the waiting time for candidate bulls was completely eliminated. In addition, improvement of the dairy cows showed up sooner in the new scheme by the 10th year from the start. The cumulative genetic improvement was four times greater than for progeny testing.

(3) Untested AI Young Sires

Potentially superior young animals needed to be identified early. Pedigree Indexes (PI) or Parent Average (PA) had been utilized for this purpose for many years. Pedigree Indexes are .5 and .25 of the genetic evaluation of sire and maternal grandsire (MGS) respectively. PA's could be used to rank and select young bulls. There is no better predictor of future milk production on young animals than PA. A bull's PA was calculated as one-half of his sire's Predicted Transmitting Ability (PTA) plus one-half of his dam's PTA for a particular trait. Although PA was a good predictor of the bull's eventual proof, some young sires will come through with proofs below their parent average, while others will come through with higher proofs. The net result was that the average proofs for a group of bulls was usually quite close to the overall average of the bulls' PA (Powell and Norman,1989).

One of the weaknesses of the PA had been the accuracy of predicted transmitting abilities (PTA) for bull-dams. Though the implementation of the animal model greatly increased the accuracy of cows PTA, there was still a tendency of overestimating ETA for bull-dams (Ferris et al. 1991, Graham et al, 1991, Mao et al, 1991). Zhang et al. (1994) investigated that indexing young bulls for AI were compared relative to subsequent progeny tests on the same bulls. Correlations among the pedigree indexes and eventual proofs for traits in the Lifetime Profit Index ranged from .6 to .8. Of the top 40% of young bulls on the basis of pedigree indexes, 86% (93 out of 108) were also in the top 10% on actual proofs. No bull with PI in the bottom 30% had an actual proof that reached the top 10%. So, the key to use semen from untested young bulls should not mate a large portion of the herd to a few young sires (Powell and Norman,1989).

Thompson and Freeman (1972) found that the use of untested sons of progeny tested bulls gave the most rapid genetic gain in small populations. Hunt et al. (1974) compared estimates of genetic gain from progeny testing programs with estimates when the same population was bred only to young bulls. The all young bull studs gave similar rates of genetic progress to progeny testing schemes for the smallest cow population.

Multiple Ovulation and Embryo Transfer

Where PTAI were neither available nor inadequate, bulls for the commercial population could be produced from a MOET nucleus scheme. Success of such a scheme would depend on the successful use of the advanced technology. MOET offered a chance to improve selection intensities in the female pathway. Compared to progeny testing, the accuracy of evaluation was reduced since the number of sibs was usually lower than the number of progeny. For small populations, however, the differences in accuracy of evaluation may not be large since the number of progeny per sire for test bulls could also be quite low. Moreover, accuracy in evaluation would improve as success rates with MOET improve. With MOET, bull selection could be made to predict a bull's breeding value by the information on all collateral relatives (both paternal and maternal full sibs and half sibs). The generation interval could be reduced when using sister records instead of progeny records resulting in expected increased genetic gains. There were many different MOET breeding schemes to select superior bulls. Ruane (1988) reviewed these schemes and the rates of genetic change possible. MOET nucleus schemes offered the highest rates of progress of all the schemes that use MOET. Adult MOET nucleus schemes were the more feasible ones to adopt (Ruane, 1988).

MOET nucleus schemes were sensitive to embryo transfer success rates. Qualified and experienced personnel and good recipient herd health programs were therefore a must. Otherwise a proportion of cows fail to respond to super-ovulation and yield no viable embryos or fewer embryos than expected. In Canada, the proportion of cows selected that fail to respond was 20% (Lohuis et al., 1990). This would reduce female selection differentials. When superior cows that failed to respond were replaced with cows of lower genetic merit, lower rates of progress were achieved. Low success rates could also result in a smaller number of families giving reduced accuracy of evaluation for the bulls. Therefore, more donors than required should be selected. Embryo yields per cow per flush in the field average about 7 (Lohuis et al.,1990), although yields of 8 embryos per cow per flush were possible with experienced technicians(Hasler et al., 1987). Pregnancy rates of 66% were possible with non-surgical transfers and will increase with experience and practice (Rowe et al., 1980). Rates of 65% were reported for the British MOET nucleus scheme (McGuirk, 1989) and 45% for field MOET schemes in Canada, respectively (Lohuis et al., 1990).

Another area of concern with MOET nucleus schemes in a limited size was the rate of inbreeding and the result of reduction in genetic variation. This would result in lower rates of genetic change. Inbreeding depression would have an affect on both fitness and production and reproductive performance (Falconer,1989). Inbreeding was important with MOET schemes since the nucleus herds were likely to be small. The smaller the number of donors, the lower the expected rate of progress, and the higher the risks associated with inbreeding (Ruane and Thompson, 1991). The number of bulls required for the commercial population and the level of inbreeding to be tolerated determined the herd size. In a small nucleus herd, inbreeding would be limited if the initial base population was of a wide genetic background, if factorial mating designs suggested by Woolliams (1989) were used, and if the nucleus was kept open to introducing foreign germplasm of genetic material from either a foreign population or the local elite population. McCuirk (1989) suggested that a smaller herd was acceptable only if it was possible to introduce outside animals of high genetic merit to the herd after the program had commenced. High inbreeding rates were also due to the use of family information, which increased the frequency of selection of sibs. Juga and Maki-Tanila (1987) and Ruane and Thompson (1991) showed genetic response in milk production varied from 1.0% to 1.26% per year for the alternatives studied. These rates were substantially lower than the 1.78% to 2.24% per year predicted for the Adult MOET nucleus schemes in Nicholas and Smith (1983).

Fewson (1989) derived the optimum number of donor cows for different cow population sizes. For a population size of 100,000 cows, he recommended 50 to 100 donor cows be selected. Dekkers and Shook (1990) did a financial analysis of a breeding company running a progeny test scheme and adopting a MOET nucleus scheme. They found that closed adult nucleus schemes were competitive to the conventional progeny test scheme only for large nucleus herds.

Dekkers (1992) reported conventional AIPT schemes could be considered as dispersed open nucleus breeding schemes in which the nucleus consists of daughters resulting from bull-dam matings. With selection on animal model BLUP EBV across age groups, use of MOET on bull-dams for the production of young bulls was then theoretically as effective in capitalizing on MOET with regard to genetic improvement as utilization of formal MOET nucleus breeding schemes. The advantages of establishing a separate nucleus station over a dispersed (open) nucleus herd mainly pertain to logistics and to the quality and quantity of station versus field information, where quantity refers to the amount of information on sibs and the number of traits evaluated.

Marker Assisted Selection

In current animal breeding schemes, prediction of genetic differences between animals was based on phenotypic observations, which depend on genetic and environmental factors. Restriction fragment length polymorphism, variable number of tandem repeats, and polymerase chain reaction made it possible to identify genetic differences directly at the DNA level. These differences, which were called genetic markers, were not likely to be quantitative trait loci (QTL) themselves, but they may be linked to QTL (Soller, 1978). In a breeding scheme, use of phenotypic and marker data could provide more information than phenotypes alone. When marker data were included in the selection criteria, this process being referred to as marker-assisted selection (MAS), accuracy of selection would be increased. Marker data could be collected early in life, allowing selection at an early age. In this respect, MAS is similar to juvenile indicator traits. The use of genetic markers in animal breeding involves four steps: 1)The search for genetic markers; 2) establishment of a linkage map of the markers; 3) detection of associations between markers and QTL; and 4) use of marker-QTL associations in the breeding program (Woolliams and Smith, 1988).

Several quantitative trait loci (QTL) for milk production traits have been identified in dairy cattle (Spelman et al., 1997; Vilkki et al., 1997). QTL could be utilized in marker-assisted selection (MAS) breeding schemes. MAS for dairy cattle had been evaluated in many studies and have shown that the rate of genetic gain could be increased by the implementation of MAS (Brascamp et al., 1993; Kashi et al., 1990, Mackinnon and Georges, 1997; Ruane and Clooeau, 1996; Spelman and Gairick, 1997).

Genotype-environment interaction

The introduction of foreign germplasm into another country was possible existence of genotype by environment interaction. A trait measured in two different environments is to be regarded not as one trait but as two. If the genetic correlation is high, then performance in two different environments represents very nearly the same trait, determined by very nearly the same set of genes. If it is low, then the trait is to a great extent different, and high performance requires a different set of genes (Robertson, 1959b; Dickerson, 1962; Yamada, 1962). Such interactions had been shown to be unimportant among temperate countries (Garabano et al. 1989; Sieber and Powell, 1989). Falconer (1989) proposed that the genetic correlation between the expression of the same genotype in two different environments could be used as a measure of genotype by environment interaction. The product-moment correlation between breeding values of sires estimated in different environments was not influenced by differences in variation. This was the method used in several studies (e.g. Petersen, 1975; Danell, 1982). When genotype by environment interactions exist, the best genotype in one environment was not the best in another. If the genetic correlation between countries was low, breeding strategies based on local selection programs may be superior to those based on imports of genetic material. For moderate genetic correlation, strategies based on imports could be adopted. The response in the importing country should be estimated as correlated response. The results reported for GXE interactions between temperate and tropical countries were inconsistent and inconclusive possibly due to limited sets of data available. In McDowell et al. (1976) the genetic correlation estimates for milk production in Mexico and the USA was high (.86) whereas in Abubakar et al. (1987), it was moderate (.51). The lowest genetic correlation in performance between countries found in the literature was .08, between Sri Lanka and Denmark (Buvanendran and Petersen, 1980). Chauhan (1983) reported the genetic correlation between Denmark and India was .11 while that between USA and India was .7.

INTERBULL estimated of genetic correlations among countries. Estimates would normally range from .86 to .89 between two Northern Hemisphere countries and from .75 to .78 between a Northern and a Southern Hemisphere country. The model of national evaluation was also taken into consideration: countries with similar national evaluation models were assigned higher genetic correlation estimates.

Strategies based on importation of genetic material

The primary objective of importation of germplasm was to bring in genetic material of higher genetic merit from foreign population and thereby raise the average genetic mean of the importing population. The genetic impact depended on 1) How often imported material was made; 2) the imported material was used for SB or SC; 3) the difference in genetic means between the importing and the exporting country; 4) the importance of genotype by environment interaction. Progress was likely to be fast when the exporting country was much superior, when a large proportion of cows were mated to foreign bulls, when imports were continuous rather than only once, and when genotype by environment was not important. The main disadvantage of import strategies was cost of imported germplasm. The importance of genotype by environment interaction between importing countries and exporting countries had to be determined. If it was not important, then strategies based on imports of genetic material or those combining imports with local selection could be adopted (Smith, 1988).

For a developing country, semen was imported to breed commercial cows. Therefore, the semen need not be from the best bulls in the exporting country but the bulls should be of higher genetic merit than average bulls in the importing country. The price of semen from such imported bulls should be competitive. Usually, semen importation programs have always been combined with selection program.

Economic returns on farm level for semen importation were calculated for Colombia, Mexico and Venezuela (Holmann et al., 1990). Average economic returns were negative for the three countries. This was because production levels in the three countries were low so the authors recommended semen importation only in high producing herds and when conception rates were high. Since production conditions and production levels were favorable in importing countries, it may therefore be worthwhile to investigate this strategy.

Holmann et al. (1990) found that local processing of semen collected in Colombia from imported bulls was better in economic terms than importing semen. A group of young bulls could also be generated from imported embryos, produced by mating the best cows and bulls in the exporting country. Young bulls from imported embryos were used untested or some could go through the progeny-testing scheme. Population parameters for the importing countries dairy population were within the range for which this strategy was suitable. Using ET to produce young bulls for progeny testing has been estimated to increase genetic gains by up to 15 percent (Petersen and Hansen, 1977, Hill and Land, 1976) and financial gains by over 40% (Dekkers and Shook, 1990).

Computerized model to study breeding schemes

A model for studying breeding scheme would use mathematics, statistics, and computer techniques to create the possibility of more extensive experimentation, describe the phenomenon in questions, bring about relations in conditions and approaching those to the real world so as to obtain a fuller understanding of a breeding scheme. So, the model would provide information that may be too expensive or too time consuming to obtain by experimentation. The application of model to animal breeding or even livestock science and production research has increased greatly in recent years. Four reasons could be forwarded to explain this phenomenon. In dairy cattle breeding schemes, genetic improvement is dynamic in nature and influenced by various fixed and random effects and based upon biological productivity such as yield, the factor of fertility, reproductive capacity, and mortality. Genetic improvement in a dairy population is accumulated over time. So a computerized model is suitable for the study of this topic to obtain a more complete understanding in the real dairy cattle breeding world.

The types of model given by France and Thornley (1984) could be divided into empirical and mechanistic models, static and dynamic models, and deterministic and stochastic models. An empirical model sets out principally to describe, whereas a mechanistic model attempts to give a description with understanding. A static model is a model that does not contain time as a variable while a dynamic model contains the time variable explicitly. A deterministic model is one that makes definite predictions for quantities (such as genetic progress) without any associated probability distribution. A stochastic model, on the other hand, contains some random elements or probability distributions within the model. Stochastic, semi-stochastic and deterministic models had been suitable and used to study genetic improvement in long-term breeding experiments (e.g. Kislev and Rabiner, 1979; Dekkers and Shook, 1990; Woolliams, 1989; Dekkers et al.,1996). Stochastic models allow a more realistic representation of the process of selection on a quantitative character. They also allow calculation of the variation in response associated with breeding programs. However, stochastic simulations required a large number of replicates. When stochastic model simulated several strategies and long term predictions for a large population, they can be time consuming. Deterministic models predict the results of given breeding schemes using formulae that were derived theoretically and provide an understanding of the underlying parameters. Because of their lower computational requirements, a large number of alternatives breeding schemes can be evaluated. Therefore, deterministic models were selected for this study of several breeding strategies.

GENETIC RESPONSE FROM SELECTION

Robertson and Rendel (1950) developed an equation for predicting genetic change based on theoretical considerations. The equation was deterministic in nature to predict expected genetic change for a defined selection criterion, usually interpreted as genetic value for a single trait. Symbolically, the equation for expected superiority is

$$\Delta G = i * r_p * \sigma_a$$

Where ΔG : expected genetic response
i: selection intensity
r_p : accuracy of genetic evaluation , p is the top fraction selected based on genetic merit
σ_a : additive genetic standard deviation for milk yield.

Some conditions underlying the equation were normality, truncation selection for the selection criterion, genetic gain at equilibrium and additive genetic variation constant over time. The equation shows the superiority in average breeding value of selected animals over those available for selection. Genetic improvement per year depends on the generation interval, or the average time in years between when an animal is born and when its offspring is born.

These factors can be used to determine which scheme would be expected to result in the largest gain per year. For most traits, additive genetic value makes up most of the genetic value and is the part, which is transmitted directly to progeny. Thus, selection will be assumed to be for additive genetic value.

Rendel and Robertson (1950) predicted genetic change based on four selection pathways: sires to breed bulls (SB), sire to breed cows (SC), dams to breed bulls (DB) and dams to breed cows (DC). The estimator of annual genetic change (Δg) was given as:

$$\Delta g = \frac{\Sigma \Delta G}{\Sigma L}$$

Where ΔG is the genetic superiority for each of the 4 pathways and L was the generation interval for each of the 4 pathways. Sires of Bulls (SB) were used by Al organizations to produce young sires for sampling. The SB contributes the greatest to genetic progress because they were highly selected. Accuracy of selection was also high because all SB were progeny tested and accuracy usually is over .9. Dams of Sires (DB) were highly selected from over the top 2% of all cows in the population. Accuracy of selection was less than the SS path, ranges from .5 to .65. Sires of Cows (SC) were chosen by farmers to breed their cows. Intensity of selection was high but less than for SS. In general, about one of five young sires was returned to heavy service, and 13% of the tested population was used for progeny testing young sires. Dams of Cows were chosen by dairy farmers to leave offspring in the population. The DC path contributes the least to genetic progress because of low selection intensity (Everett, 1984). Korver and Renkema (1979) found that the rate of genetic progress was hardly affected by culling females for production. Therefore, the cow to breed cows pathway was assumed no effect on genetic progress for all strategies.

Most progress was made in selecting sires to produce the next generation of bulls, with 43% of the total genetic progress in this path. The second most influential factor in genetic progress comes from selecting dams of future bulls (33%). Selecting a group of sires to breed cows accounts for 18% of the total genetic progress, whereas the selection of dams to produce cows was the least important, accounting for only 6% of the total (Rendel and Robertson, 1950).

Discrete generations and overlapping generation

Discrete generation occur when all of the offspring are kept till the last-born was mature. Selection was then made and the selected individuals were all mated at more or less the same time. The generation interval was the interval between the matings made in successive generations (Falconar, 1989).

In dairy cattle populations, the generations are not discrete but were overlapping.

When generations overlap, the selected offspring were mated as soon as they were mature. The generation interval could be calculated as the average age of the parents at the birth of their selected offspring. This means that the individuals present at any time were of different ages and at different stages of their life-cycles. Furthermore, individuals differ in length of life and consequently in their opportunities for reproduction. The longer-lived individuals had greater chance of contributing offspring to the next generation than the short-lived do. Cows presented at any time are of different ages. Selection of parents was more or less a continuous process. Because the genetic trend exists, animals of different age classes should be regarded as coming from different distributions of genetic values with different means and variance. Response from the selection of parents could be calculated by multiplying the genetic superiority of parents by the proportion of their genes present in later generations (Ducrocq and Quaas,1988).

Gene flow procedure

Hill (1974) presented gene flow procedure using matrix formulation based on the Rendel and Robertson (1950) formula. With this procedure, response from the selection of parents was calculated by multiplying the genetic superiority of parents by the proportion of their genes presented in later generations. Ruane and Smith (1989) used this method to evaluate MOET schemes. The gene flow model used was:

$$\mathbf{M}(t) = \mathbf{P} * [\mathbf{M}(t\text{-}i) + \Delta\mathbf{G}(t)]$$

where **M**(t) was a vector of average genetic merit of animals at time t, **P** was a gene transmission matrix, **M**(t-i) was a vector of average genetic merit of animals at time (t-i), and Δ**G**(t) was a vector of the genetic superiority of selected animals.

The time-dependent population inventory approach

Ducrocq and Quaas (1988) presented a time-dependent population inventory approach for predicting response for a dynamic selection system. The approach would first identify newborn female groups that come from the same age group sires and the same age group dams in the year. Then compute the with-in group selection superiority and genetic merits of the selected parents who contribute genetic gains to the newborn. The estimate of the annual genetic progress of the cow population in the year was the weighted genetic merit mean of different newborn animal group.

Realized genetic gain

Estimates of genetic gain in dairy cow populations have not been equal to theoretical gain. Realized genetic progress should be monitored to evaluate the success of breeding programs (Van Vleck.,1977.,1986., Pearson.1984). Many studies have examined genetic trend by regressing estimated breeding values on time (Lee et al., 1985, Powell et al., 1977) or regressing of production on time (Powell and Freeman. 1974). In those studies, actual gain was considerably less than what was possible under ideal circumstances.

Van Tassell and Van Vleck (1991) estimated average genetic selection differentials for the four paths of selection for each year of birth. Selection differentials for paths of sires of bulls, dams of bulls, sires of cows, and dams of cows averaged over all years were 405, 395, 239, and 42 kg respectively, and for the most recent 5 years 884, 598, 235, and 28 kg respectively. Genetic trend based on the average selection differentials and generation intervals would be 34.9 kg/yr, but based on the latest 5-yr periods and considering parents of grade cows, the genetic trend would be 57.2 kg/yr.

Breeding experiments have to maintain an unselected control population, which are expensive to maintain because they quickly fall behind selected lines for productivity. Legates and Myers (1972) reported direct and correlated responses to selection for milk yield with control lines. Estimates of annual response for milk yield were 121 kg for North Carolina Holsteins. Hickman (1971) found an annual trend of 4.5 kg for fat from selection for solids yield of Holsteins. Boettcher et al. (1993) reported a selection experiment that was conducted over a 25-yr period to measure long-term responses to selection of Al sires based on milk alone. The genetic trend from 1967 to 1988 for the selection line was estimated to be approximately 125 kg/yr.

Reasons for realized genetic gain less than theoretical gain

1. Generation Intervals

Generation intervals were likely to be much longer than necessary, especially for dam of bull and sire of bull paths (Westell.1984,.Lee et al., 1985). The sum of paths in Al situations might be about 30 years, whereas the theoretical goal was 24 to 25 years. If gain was predicted to be 100 kg per year, assuming a summed interval of 24 years, the gain was reduced by 20% to 80 kg per year.

Van Tassell and Van Vleck (1991) estimated generation intervals averaged for all years by path were 10.2, 6.4, 9.3, and 5.1 yr. For the most recent 5 years, the interval were 11.0, 6.4, 8.9, and 4.9 yr respectively. Estimates of annual trend were considerably less than the potential rate of 96 kg/yr because of longer than necessary generation intervals, and smaller selection differentials than theoretically possible.

2. Selection emphasis on other traits

A common practice among bull studs was to set minimum levels for several factors including type and fat test that must be met before a cow qualifies as a bull dam no matter how good her genetic evaluation for production. Each such minimum standard, in theory, would reduce the expected genetic superiority for production. These results indicate that selection practices in that period were not optimum for maximum improvement of milk production. Decreased emphasis for non-yield traits, while reducing generation intervals, could dramatically improve genetic trend in the future (Van Vleck, 1986).

3. Problems with genetic evaluations

A major concern has been the failure of genetic evaluations of bull dams to predict their sons evaluations as well as theory would predict (Vinson, 1984). The general result has been that evaluations of dams based on other than first lactation records hadn't increased accuracy of predicting sons' proofs (Murphy et al., 1982). In general, the use of only first lactation records in the genetic evaluation of the dam results in regressions of son's or daughter's evaluation on sire's proof, dam's evaluation, and maternal grandsire's proof. Such regression agreed closely with theoretical approximations of these regression coefficients. When the dam's evaluation was based on all lactation records, the regression coefficient for her evaluation was smaller than theory would predict. The regression coefficient for the maternal grandsire's proof seemed to compensate for the loss of value of the dam's evaluation by changing from an expected small negative coefficient to a small positive coefficient.

4. Inbreeding

Inbreeding could lead to a depression in phenotypic performance (inbreeding depression) due to dominant gene effects. Keller et al. (1990) found that the reductions in genetic response due to inbreeding depression were m that ore severe than reductions due to inbreeding effects on additive genetic variance alone. The rates of inbreeding were high with selection in small populations. However, the rate of inbreeding was reduced by introducing foreign unrelated animals into the breeding stock and was not important when populations were open to exchange of stock. Inbreeding would be important when progeny testing in a closed population and in the nucleus herd for the MOET scheme.

The rate of inbreeding per year (F) was estimated using Wright's formula (1931):

$$F_D = \Delta F * D * h\sigma_p$$

Where F_D is inbreeding depression in a unit, D is the % depression per percent increase in inbreeding coefficient.

5. Genetic variation (σ^2_a) and Bulmer effect

Genetic variation refers to the variability of additive genetic values within a population for milk yield under selection. It relates to the difference between the average individual and the top individuals. The more superior the top individuals are over the average, the grater the potential to make genetic gain through selection.

Bulmer (1971) showed that the genetic variation was temporarily reduced by the selection of parents and ancestors, but regenerates quickly when selection was relaxed. This is because a group of selected parents represents one tail of the phenotypic distribution, and in consequence their phenotypic variance must be less than that of the whole population from which they were selected. So when calculating the genetic responses, the temporary reduction in genetic variation due to selection of parents and ancestors should be taken account (Falconer, 1989).

6. Other factors

Records that provided misinformation possibly because of misidentification, or preferential treatment, or non-random mating and treatment reduced genetic progress primarily through the dam of bull and sire of bull paths.

Selection differentials were much smaller than thought possible for SC and SB, which might be due to emphasis on traits other than milk production and high percentage of sampled sires returned to service with little selection based on production traits.

ECONOMIC EFFICIENCY OF A BREEDING SCHEME

It is important to include all relevant costs and returns when evaluating the efficiency of a breeding scheme. A sound investment of a breeding scheme should give high genetic progress at reasonable costs and maximum benefits to the dairy industry. Costs are compared with returns to determine which scheme gives the greatest benefit. The cost and returns from genetic improvement for different breeding schemes accumulate over time and are realized over different period. They must be expressed in a comparable unit. The usual method of comparison is through discounting future costs and revenues to current values. The net present value (NPV) can be used as an economic evaluation criterion. In economical comparison of the expected benefits from different breeding schemes, the production of whole population of cows is of interest.

The benefits of genetic improvement

The major benefit of genetic improvement is the additional milk yield produced by improved cows over that of cows from current breeding scheme. There are some secondary benefits due to increased milk production. For example, increased production will influence all of the commercial dairy population as well as other production sectors of the dairy industry. These include the increased imports of dairy genetic material, local breeding infrastructure, and the growth of milk processing and feeds industries. All these secondary benefits are difficult to evaluate and are therefore excluded in this study.

The total costs of breeding scheme

1. Milk production costs:

Milk production costs are the costs incurred by the dairy herds. They include buying the farm, building the dairy, fencing, electricity, labor, dairy equipment, tractor, feeds, veterinary services, medicines, shipping, selling charges, electricity, insurance, and miscellaneous costs. These costs and basic overhead expenses (e.g. living expenses of farmers) are assume to remain the same no matter what scheme is adopted and are all excluded from the analysis.

For a fixed herd size, costs might change slightly with increased milk production level. Breeding costs would increase because more semen is required for higher producing cows. The milk costs for increased production due to genetic improvement only considered feed costs and health costs in most studies (Ferris and Troyer, 1987; Mpofu et al., 1993).

2. The investment costs:

These are the costs for setting up a breeding scheme and are incurred once at the beginning of the program. However, If some items need replacement during the operational period, the replacement costs for such items are also considered as investment costs. Some items may outlast the evaluation period and will have a salvage value. Other investment costs are fencing and building, electrification, roads, building a laboratory, lab equipment, semen storage facilities and bull handing equipment. For semen import schemes, the main investment costs are storage building and semen storage equipment.

3. The operation costs:

The operation costs are recurrent costs needed to run the scheme every year. For most of schemes, the operation costs include bull procurement costs, bull maintenance costs, and semen collection, storage and distribution costs.

The bull procurement costs are the rearing costs up to the time of purchase by bull station. Bull maintenance costs per bulls per year include labor, feed, veterinary services and medicines, stationery, and some miscellaneous costs. The operational costs increase from year to year in the first five years as the bull station reaches its full capacity.

For schemes involved in imported semen, the main operating costs are the cost of semen and shipping, handling and export charges as well as storage and distribution costs. Imported semen are priced according to their percentile group for PTA M. Other running costs include semen storage costs.

For the MOET scheme, the operation costs are the costs of collecting and transferring embryos, costs of collecting semen, administrative costs (to screening and selecting donors) and high technical input. For the scheme involved in embryo import, operation costs include the cost of embryos, costs of mating, shipping, and handling and export charge as well as embryo transfer.

4. The contingency cost:

Contingency cost is the cost to allow for losses from damage during handling semen. The number of semen or embryos imported is more 1.05 times than that required.

Evaluation criteria of economic efficiency

There are many criteria for evaluating breeding scheme economic efficiency. Net Present Value (NPV) was the most commonly used (Petersen et al.,1974., Fox et al.,1990., Dekkers and Shook.1990a).

The NPV is the net present value of the incremental income generated by the investment. The following equation is used to calculate NPV:

$$NPV = \sum_{t=1}^{t=T} \frac{B_t - C_t}{(1+d)^t}$$

Where B_t is the value of benefits for year t, C_t the cost in year t, T is the period of evaluation, and d is the discount rate. When the calculated value of BCR is less than 1 (i.e. the present value of costs at the given discount rate are higher than the present value of the benefits), it means expenditures and investment costs are not fully recovered.

If the NPV is negative the present value of the benefit stream is insufficient to recover costs. Therefore, independent projects that give a positive NPV are the ones to be selected. The NPV is the preferred measure when the projects are mutually exclusive (Gittinger, 1982) and can be used to rank such projects. Mutually exclusive projects are projects of a nature that if one is chosen, the others cannot be undertaken. The strategies to be evaluated in this study are mutually exclusive. The strategy giving the highest NPV is the one to be selected. The problem with the NPV measure is that it can only be used when the estimate of the discount rate is accurate.

DAIRY CATTLE INDUSTRY IN TAIWAN

Background

Taiwan is located on the Tropics of Cancer in the Pacific Ocean east of China mainland and consists of the main island Taiwan and the Pescador Matsu and Kimem Island. The island Taiwan covers an area of 35,989 km^2. The population is almost 22 million. The climate is mainly subtropical and in the southern parts tropical. The average temperature for the island is 28°C. Average temperatures are 15^O to 20^OC in the winter and 30^O to 35^0C in the summer. July is hottest month and February the coldest month, with average temperature of 32^0C and 16^0C, respectively. The average relative humidity is 85% with a variation from 70 to 98 %.

Dairy Industry

Taiwan is hardly an ideal place for dairy farming. Milk is produced only from Holstein. Due to high temperature and high humidity, the main constrains that dairy farmers have long been confronted are the cows' summer infertility syndrome, mastitis, and foot and leg problems. Especially, the summer infertility influence the cows to produce less milk when the price is up in summer and to produce more when the price is down in winter. Because of the government's policy support and the increased consumer demand for fresh milk, however, the dairy industry has been growing at some 16% annually for the past years. Yet, the self-sufficiency of milk and milk products in total still remained at 15-20% in recent years. A large variety of dairy products are imported and sold at relatively low prices. To be competitive, almost all raw milk produced locally is processed into fluid milk products and recently some milk has been processed into yogurt.

Milk production costs and benefit of milk

Production costs varied from farms to farms and were influenced by herd size and herd production levels. The costs of milk production include feed, labor, veterinary expenses and medicines, tractor operating costs, selling charges, electricity, insurance, transport costs (delivery of milk to depots) and some miscellaneous costs. The major costs were feed (50% of total costs), labor (12%), veterinary expenses and medicines (8%) and transport costs (8%). For feed costs, cows were fed according to production and NRC requirements Labor costs include wages. Tractor operating costs cover fuel, lubricants, repairs and maintenance. Veterinary, medicine and miscellaneous costs can be grouped into one. This group are included dipping, semen price and AI fee, detergents for the dairy equipment, etc. These were expressed as a percentage for one-kg milk production.

Farmers were paid for the amount of milk produced. The basic price of milk is adjusted for the hygienic and compositional quality of the milk delivered. In 1997, the standard milk price was $US.62/kg of milk, containing 3.5 percent fat. In 1997, benefit from milk per kg were $NT4.55/kg ($US0.14/kg) obtained from the file of Council of Agriculture.

Dairy farming

There are 843 dairy farms in Taiwan in 1997. The average herd size reached 113 heads with a range from 40 to 500 cows per herd, and the average land holding was 1.86 hectares. In order to reach an economic scale of 100-150 heads (total number), pregnant heifers had been imported in the past ten years and this made the herd size increased more rapidly recently. Most dairy farms belong to a family type with 2-3 persons. Due to mechanization, they are able to manage a herd between 100 and 150 cows in 10 working-hour per day.

There are two main local grasses used for dairy cattle, namely, Napier grass and Pangola grass. Corn silage has been getting popular in recent years, because of its competitive price. Alfalfa hay, in the form of bale and cubes, and bale Bermuda grass hay have been importing from North American countries and used as supplement. A considerable amount of local produced agriculture by-products such as peanut vine hay, corn stover, tomato pomace, soybean pomace, brewers grains, sorghum distillers grains are used in dairy rations. As for the concentrate, most corn and soybean depend on importation. Since 1985, computer feeding of concentrate had been introduced, which made the frequently and accurately feeding of concentrate according to body weight, parity, milk production, and fat percentage of milk. More recently, Total Mixed Ration (TMR) system has been adopting by many dairy farmers. Farmers using TMR system would save much labor, reduce cows' digestion disorder, get much more stable milk composition, and increase milk production as well.

Being in a hot climate, dairy farmers built simple yet practical barns with both sides open, except those near the seashore and in the northern area where a wall on one side is needed. The new or remodeled barns usually have enough space for mechanical operation and also they are high and have insulated roof for good ventilation. The free stall barns are concrete floors with some bedding with rice hulls and sawdust. Most farms milk cows in their milking parlor with pipeline milking machine. Yet a few small farms still use bucket system to milk cows in the barn. To increase efficiency and save labor, automation including automatic crowd gate, automatic milking recording, automatic teat cups remover are gradually become popular.

Breeding related programs and practices

1. Dairy Herd Improvement (DHI) program

There were 230 dairy herds with about 13,000 milking cows enrolled in 1996. The average herd size for milking cows was 54 cows with an average parity of 2.85; the average milk yield (305-2X-ME) was 6,572 kg and the average daily milk yield was 20.3 kg. The lowest daily milk yield was in August (17.67 kg); the highest was in December (21.06kg). The average percentage of milk fat and protein were 3.68% and 3.16%, respectively. The average milk somatic cell count (SCC) was 60,080/ml. The cows were calved for the first time at an average age of 26 months with calving interval 15 months. The average calving interval was 446 days and the average number of days dry before calving was 110 days. Calving was generally throughout the year, although most calvings were during the six months from October to April and the frequency of calving declines from May to September. The average days open was 163 days, and the services per conception were 2.7. The data indicated the reproduction efficiency must be enhanced, and milk production will be upgraded if the SCC goes down.

As the current payment scheme for milk yield include a penalty or premium related to the bulk tank SCC, farmers are being forced to participate in DHI in the next few years and the goal is to have 50% farms on DHI.

2. Artificial Insemination (AI)

AI was introduced into Taiwan in 1970 and now is available to all dairy farmers through extension service or done by farmers themselves. About 80% of cows are artificially inseminated to frozen semen from either local untested bulls (20%) or foreign progeny tested bulls (60%). Most of imported semen was from the US, and some from Canada, Japan and Holland. Emphasis was put on genetic merit for milk production and price. There is a trend that selection pressure for the SC pathway is increasing. Price of imported semen ranges from US$12 per straw to $US 50 per straw while semen from local bulls is $US6.

A governmental bull station was established to select young bulls, to collect semen and sell to farmers. Because only small proportion of cow population was on DHI, bulls raised at the station were not progeny tested. But they are from mating which are of high genetic merit of parents. These untested bulls provided semen for AI service to mate about 20 % of cows. The farmers would like to use semen from these untested bulls because of their higher conception rate, cheaper price and more or less contribution to the genetic progress.

About 20 % of cows were settled by natural service bulls to promote the reproductive efficiency, especially during the hot season from June to October. Some cows were sired from imported semen with their PTA M from the top 10% of foreign progeny tested active bulls with 81% REL.

3. Embryo transfer

Embryo transfer technology (ET) was introduced into Taiwan in 1980 and the importation of frozen embryos was introduced in 1985. Success rates of ET were 40% for frozen imported embryos and 60% for fresh embryos produced from local cows (Lee, 1993). The primary reason for embryo imports in Taiwan is to produce superior bulls and high genetic merit females for production. Importing embryos instead of bulls are more efficient due to easy transportation and less restrictive health requirements. Animals born from local recipients and raised under local conditions should be more resistant to the local diseases.

4. Culling and importation of live animals

A high involuntary culling rate and a low reproductive efficiency results in no selection for dams of cows and cause very little population expansion. The main reasons for involuntary culled cows are reproductive sterility, mastitis, and foot problems. The percentage for each of reasons was 33%, 21%, and15% respectively. Low reproductive efficiency is due to 2.7 AI services per conception resulting in a calving interval of 16 month.

Since 1986, farmers who wanted to expend their herd size imported heifers from foreign countries. Pregnant or yearling Holstein heifers were brought into Taiwan, mainly from the North American and some from Canada, Australia, New Zealand and Japan. From 1985 to1992, importation of pregnant heifers of 5~10% as cow replacement per year was practiced from the US, Canada, and Japan.

CHAPTER 2

EXPECTED RESPONSES FROM SELECTION ON CURRENTLY AVAILABLE CRITERIA OF GENETIC MERITS

ABSTRACT

Genetic responses in 20 single traits and in five indexed merits were estimated, when selection was based on a variety of criteria that were currently available to the U.S. dairy cattle breeders. Single trait selection criteria were PTA values for milk, fat, protein, type, somatic cell score (SCS), and production life (PL). Yield merit criteria were MF$, MFP$, CY$ and total merit were NM$, and TPI. Comparisons were made after one round of selection in a discrete generation with fixed selection intensity and accuracy. The greatest response in milk yield was from direct selection on PTA of milk, but responses from selection on MF$, MFP$ and NM$ were only slightly less. Increase in fat yield was, as expected, the greatest when selection was directly on PTA of fat, but the increase in protein yield was the greatest from CY$. The greatest response in type could only be achieved by selecting PTA of type and TPI. Selections on most criteria would lead to an increase in SCS with the least increase from selection on PTA of fat and NM$, but selections involving type resulted in large negative responses. All selection criteria would lead to favorable responses in linear type traits with a few exceptions, including fore udder attachment, udder depth and teat placement. The greatest return in any merit was obtained by selection directly on that specific merit index, but selection on PTA of yield traits and other merit indices would lead to almost as much response. Selection on PTA of type would result in very trivial positive responses in merits.

INTRODUCTION

Milk products are one of the most important food products for human consumption in the world. Dairy farming is worldwide and much work has been done to improve efficiency of milk production by breeding, feeding, and health care. Primary breeding goal has been to improve milk yield. Other traits such as fat and protein yields, type final score, linear functional type traits, somatic cell count, calving ease, milking speed, and productive life may be also important depending on breeding goals. Whether or not these and other traits can be selected for depends entirely on if they are recorded and genetically evaluated.

Mastitis was the most costly health problem of dairy cows. Many studies were conducted on improving udder health and reducing mastitis. SCC in milk was recorded on most DHIA programs and might serve as an indicator of mastitis in breeding program (Renea.1986). As distribution of SCC is not normal, and its relationship with milk yield was not linear (Shook, 1982), Dairy Records Processing Centers transforms SCC to somatic cell score (SCS), which is the $\log_2$ transformation of SCC. Somatic Cell Score (SCS) has been accepted by the National Cooperative DHI program as a standard recording scale for SCC. SCS had been used for genetic evaluation and has become an important economic trait of dairy cattle. Genetic selection on SCS has been considered as one approach to improve resistance to mastitis in future generation (Shook, 1989; Shook and Schutz, 1994). Rates of improvement through genetic selection were likely to be slow but the cost involved in genetic enhancement of disease resistance was small compared with the large cost of treating clinical mastitis and the milk yield lost from sub-clinic mastitis (Roger, 1993; Standberg and Shook,1989.).

Productive life (PL) was the trait used to estimate genetic merit for longevity. This trait could be thought of as the ability of a cow to avoid culling. Increased productive life contributes to the profitability of dairy yield by decreasing replacement costs and by increasing the percentage of cows producing at mature levels. The productive life of dairy cows average about 3.5 yr. (Norman. et al., 1981) in US, which was much less than their biological potential. Burnside et al. (1984) concluded that milk yield was economically twice as important as herd life. Due to low heritability and PL is expressed at a later age than the other traits. Many researchers have tudied the importance of productive life in dairy selection programs. Although study methods differed, findings were quite consistent. VanRaden and Klasskate (1993) suggested a method to evaluate PL from completed and predicted data and made PL evaluation available. PL had higher economic value than many traits currently evaluated and might be one-third as important as yield, based on an average of recent estimates (Allaire and Gibson, 1992; Dekkers.1993.; Harris and freeman,1993; Van Arendonk.1991).

One of the purposes of the linear type classification program was to identify and to emphasize traits associated with longevity and mastitis resistance. Feet and legs have always been an important issue in dairy cattle breeding. Several studies have been conducted to put on feet and leg traits and their correlation with stayability (McDaneil, 1995; Uribe et al., 1995). Many studies have also been conducted to find out the relationship between linear udder traits and SCS (Seykora and McDaniel, 1986; Rogers,1990; Schutz and VanRaden,1993). They concluded that udder depth, fore udder attachment, teat placement had relationships with SCS.

Currently, dairy farmers in U.S. has more than 30 selection criteria available from genetic evaluations done at USDA and other sources. Among these criteria, there were three kinds of criteria for genetic selection: 1) PTA values for selecting individual traits, 2) Product Value Indexes for selection of a composite of production traits, and 3) Total Merit Indexes for selection of a collection of traits deemed to be economically important.

For single trait selection, PTA value (Predicted Transmitting Ability) has been available for many traits of interest for genetic selection. Single trait selection criteria deal with only single trait improvement. It is for the goal of increase profitability and efficiency of a cow that a joint selection on a collection of traits is considered. However, which traits would be included with yield traits in the selection program and how much each trait should be emphasized are debatable issues in every dairy breeding industry. The relative importance given to these traits is different from breeder to breeder and done in different manners.

For multi-trait or merit selection, a selection index (Hazel, 1943) was used to determined appropriate weights for the traits included in a selection criterion. Merit selection criteria allows to improve several yield traits and non-yield traits simultaneously. Among efforts in the U.S., Rogers and McDaniel (1989) applied the selection index method by utilizing involuntary culling in an aggregate genotype to represent the composite costs of health, reproduction, and husbandry attributes. Traits considered in the index were milk yield, udder depth, teat placement, and foot angle. Rogers (1993) used information on SCS, udder depth, teat placement, and foot angle along with milk yield to identify optimal sire indexes. Misztal (1992) used a restricted index to calculate maximum response in milk yield and maintain udder depth at its current value. Computer software for designing selection criteria, which is also getting popular, allows breeders to place selection emphasis on the traits which they consider to have the most economic benefit in their herd (Cassell, 1986)

That selection on one trait would lead to genetic change in another trait was called correlated response. The correlated response depends on the genetic correlation between the two traits. In fact, when selection was based on one index, each of the component traits in the index would have a correlated response as well as other traits not in the index. There would also be a correlated response in another indexed merit. Genetic improvement is permanent and accumulates over time. Information on genetic responses or correlated genetic responses of all economic traits and indexed merits to various selection criteria were limited. All of these responses were useful to know to the breeders for guidance to set up their breeding program. It would be useful to the AI organization in choosing bulls' dam and in sampling young bulls. If there would be undesirable responses for some economic traits on a selection criterion, and if the breeder cannot tolerate some of these increased undesirable responses on a selection criterion, he needs to use another selection program.

The specific objectives of this study were: (1) when selection is on a single trait, estimate the genetic response of the trait undergoing selection, the correlated responses in other single traits and in indexed merit function ; (2) when selection is on an indexed merit value, estimate the expected response in that indexed merit, the expected correlated response in each of its component traits, in traits which were not included in the merit index, and as in other indexed merit function. The goal of this study is to provide information about all genetic responses of economic single-traits or indexed merits to dairy producers in Taiwan when they select semen from U.S. proven bulls with different selection criteria to improve their herds. Moreover, using this information to set up breeding schemes will not only improve in milk yield but also increase the total indexed merit to increase profitability and efficiency of a cow.

MATERIALS AND METHODS

Traits and indexed merit function

Dairy bulls in U.S. are currently being evaluated for a number of traits and indexed merits. Single traits and their selection criteria included: (1) PTA for Milk, Fat, and Protein; (2) Conformation - PTA for Type (final score) and STA for functional type traits; (3) PTA for SCS; (4) PTA for PL. PTA value is an estimate of genetics superiority or inferiority that an animal will transmit to offspring.

Three yield merits are derived based on the current milk pricing system in the US:

MF$ = $.10170(PTA M)+$.58(PTA F)

= 5(PTA M/625)+1(PTAF/22)

MFP$ = $0.031 (PTA M)+$0.8 (PTA F)+$ 2.00 (PTA P)

= 2.67(PTA M/625)+1(PTAF/22)+1.7(PTA P/19)

CY$ = -$.00220 (PTA M)+$1.98(PTA F)+$1.716(PTA P)

= -(PTA M/625)+32(PTAF/22)+24(PTA p/19)

Two Total Merit selection indexes, which are currently in use, include:

NM$ = .7(MFP$)+$11.30 (PTA PL)-$28.22 (PTA SCS-3.2)

= 10 (PTA MFP$/71)+4(PTA PL/13.2)-1(PTA SCC/1.9)

(USDA-DHIA,1995).

TPI = [$7.89(PTA P)+$2.22(PTA F)+$71.43(PTA T) +$12.18(UD)+

$6.5(FU) +$6.5(TP)+$6.5(RUH)+$4.87(RUW)+$4.06(UC)

= [3(PTAP/19.0)+1(PTAF/22.5)+1(PTAT/. 7)+. 65(UDC/. 8)

+. 35(FLC/. 85)] 50+576

Where UDC=. 3(UD)+. 16(FU)+. 16(TP)+. 16 (RUH)+. 12(RUW)+. 1(UC)

(U.S. Holstein Association. 1997)

Economic values assigned to PTA's in MF$ and in MFP$ were based on a milk price of $12.20 per hundredweight of milk with 3.5% fat and 3.2% protein and differentials of 5.8 cents for fat and 14.7 cents for protein. This was the U.S average milk price for 1994 minus the average hauling, assessments, and promotion charges (Norman et al.,1995). These figures will change every year due to changes in milk prices. The net merit index (NM) was based on MFP$ deducted for feed cost and on PL and SCS evaluation.

The second equation of each criterion was expressed as the relative weight for each component trait, which was standardized by their genetic standard deviation. The denominator terms were the standard deviations of PTAs for traits. The coefficients in front of PTAs were the relative weights of selection emphasis (Norman et al., 1995).

Calculation of genetic responses and correlated responses

The following formula in matrix notations was used to calculate the expected genetic responses and correlated genetic responses in varied combination of all situation.

$\Delta G = (\mathbf{m'Cb})/(\mathbf{b'Pb})^{0.5} * i / L$

where ΔG : the expected genetic responses and correlated genetic responses in all single traits and indexed merits

m: a vector of arbitrary weights for the traits in true value of a total indexed merit (net economic values for individual traits).

b : vector of a selection index weights for a given indexed traits in indexed merit criterion for selection which will maximize r_{TI} and true value of a trait or a merit.

P : vector of phenotypic value of individual traits expressed as deviations from pertinent smallest subclass means.

C: (Co)variance matrix between **p** in indexed merit criterion for selection and **g** in true value of a trait or a merit.

P: phenotypic (co)variance matrix.

L : generation interval
i : selection intensity

Genetic Parameters used in calculating genetic response

When calculating genetic response, some of genetic parameters are needed. In tis study, genetic estimates are used from the literature which are the results of studies for US Holstein population. Table 2-1 shows the estimates of heritability, phenotypic and genetic variances to calculate expected genetic responses and correlated genetic responses. Genetic estimates of 15 type traits were from Misztal et al. (1992). Heritabilities for milk, fat, and protein were also included in this paper which were higher than most of the other estimates of heritability using the Sire Model (SM) (Misztal, 1992; Van Vleck et al.,1987; Visscher and Tompson, 1990). The reason of higher heritability was that SM accounts for the male genetic variation whereas AM took both male and female genetic variation into account. If selection intensity for males were greater than for females, then the male genetic variance would be smaller. Another reason that higher heritabilities of yield traits were obtained in Misztal study was the use of only registered animals. Heritability and genetic variance of milk used in this study were .31 and 554,143 kg, respectively from Short and Lawlor (1992).

The phenotypic covariance and genetic covariance between traits from Tables 2-1,2, and 3 where used to construct of the phenotypic (co)variance matrix **P** and the genetic **C** matrix (co)variance. Selection intensity was fixed to be 1.4 (i.e. equivalent to selection the top 20% of bulls) and selection accuracy was .8 for all traits as well as the generation interval 6 years. The genetic responses and correlated responses are the results after on round selection of generation.

Table 2-1. Literature estimates of heritability and variances for the three yield traits (kg, 15 type traits (points), Somatic Cell Score (scores) and productive life (mo)

Traits	Heritability	Phenotypic variance	Genetic variance
Milk	.31[2]	1,787,569[2]	554,143[2]
Fat	.30	3,333	1,000
Protein	.30	2,000	600
Type final score	.29	13.4	3.8
Stature	.42	58.2	24.5
Strength	.29	46.8	13.6
Body Depth	.35	48.1	17.
Dairy form	.28	47.9	13.5
Rump Angular	.28	24.0	6.8
Thirl width	.26	44.5	11.7
Rear leg	.16	40.1	6.2
Foot angle	.13	34.6	4.5
Fore udder	.24	45.7	10.8
Rear udder high	.16	46.7	7.3
Rear udder width	.19	45.3	8.6
Udder cleft	.10	27.9	2.8
Udder depth	.25	16.3	4.1
Teat placement	.22	33.2	7.4
Somatic Cell Score	.12[1]	1.25[1]	.15[1]
Productive Life	.085[3]	174.24[3]	14.81[3]

Without superscript from Misztal et al.1992. J. Dairy Sci.75: 544
1 from Schutz.1994. J. Dairy Sci. 77: 2113.
2 from Short and Lawlor.1992. J. Dairy Sci.75: 1987.
3 from VanRanden and Wiggans. 1995. J. Dairy Sci 78: 631.

Table 2-2. Literature estimates of genetic correlations between traits

Trait	Milk	Fat	Protein	Type	SCS	PL
Milk	....	.69	.90	.16	.12[2]	.44[3]
Fat	.69	...	.78	.33	.02[2]	.23[5]
Protein	.90	.78	...	.27	.17[2]	.25[5]
Type final score	.16	.33	.27	...	-.30[4]	.39[3]
Stature	.06	.13	.13	.75	-.11[4]	.06[3]
Strength	.02	.13	.1	.62	-.06[4]	-.11[3]
Body depth	.15	.26	.23	.7	-.05[4]	-.06[3]
Dairy form	.59	.68	.67	.29	.18[4]	.40[3]
Rump angular	.18	.01	.11	-.15	-.08[4]	.08[3]
Thirl width	.11	.12	.11	.65	-.21[4]	-.02[3]
Rear leg	.09	-.01	.05	-.11	-.10[4]	.00[3]
Foot angle	.10	.13	.17	.28	-.06[4]	.08[3]
Fore udder	-.31	-.12	-.21	.54	-.41[4]	.29[3]
Rear udder height	.19	.28	.32	.59	-.19[4]	.32[3]
Rear udder width	.31	.33	.4	.60	-.15[4]	.31[3]
Udder cleft	.01	.17	.15	.52	-.12[4]	.30[3]
Udder depth	-.44	-.29	-.38	.33	-.42[4]	.24[3]
Teat placement	-.03	.01	-.01	.56	-.31[4]	.24[3]
SCS	.12[2]	.02[2]	.17[2]	-.30[4]	...	-.10[4]
Productive Life	.44[3]	.23[5]	.25[5]	.39[3]	-.10[4]	...

Without superscript from Misztal et al. 1992. J. Dairy Sci.75: 544
2 from Schutz. 1994. J. Dairy SCi. 77:2113.
3 from Short and Lawlor. 1992. J. Dairy Sci.75:1987.
4 from Rogers et al. 1991. J. Dairy Sci.74:1087
5 from Welper and Freeman. 1992. J. Dairy Sci:1342

Table 2-3. Literature estimates of phenotypic correlations between traits

Trait	Milk	Fat	Protein	Type	SCS	PL
Milk	....	.75	.93	.21	-.1 [2]	.19[3]
Fat	.75	...	.81	.2	-.07[2]	.23[5]
Protein	.93	.81	...	.22	-.01[2]	.25[5]
Type	.21	.2	.22	...	-.06[4]	.19[3]
Stature	.09	.1	.11	.32	.00[4]	.04[3]
Strength	.05	.07	.09	.24	.02[4]	.02[3]
Body depth	.13	.15	.16	.3	.02[4]	.03[3]
Dairy form	.34	.29	.32	.2	.01[4]	.09[3]
Rump angular	.04	.02	.03	-.04	.01[4]	-.01[3]
Thirl width	.08	.01	.1	.24	.0	.02[3]
Rear leg	.01	.02	.01	-.02	.01[4]	-.01[3]
Foot angle	.03	.03	.04	.06	-.01[4]	.04[3]
Fore udder	-.05	-.02	-.05	.15	-.08[4]	.10[3]
Rear udder height	.17	.15	.18	.23	-.03[4]	.11[3]
Rear udder width	.23	.20	.25	.3	-.02[4]	.11[3]
Udder cleft	.05	.05	.06	.12	-.06[4]	.10[3]
Udder depth	-.22	-.18	-.21	-.02	-.09[4]	.06[3]
Teat placement	.04	.04	.03	.18	-.05[4]	.09[3]
SCS	-.10[2]	-.02[2]	-.1 [2]	-.06[4]	...	.06[4]
Productive Life	.19[3]	.23[5]	.25[5]	.19[5]	. 06[4]	...

Without superscript from Misztal et al. 1992. J. Dairy Sci.75: 544
2 from Schutz. 1994. J. Dairy SCi. 77:2113.
3 from Short and Lawlor. 1992. J. Dairy Sci.75:1987.
4 from Rogers et al. 1991. J. Dairy Sci.74:1087
5 from Welper and Freeman. 1992. J. Dairy Sci:1342

RESULTS AND DISCUSSIONS

Genetic and correlated responses in single-trait to all selection criteria

Table 2-4 showed the genetic response and correlated response in three yield traits as well as Somatic Cell Score (SCS) and productive Life (PL) to various selection criteria for a constant selection intensity (20%) and generation interval (6 years) after one generation. Selection on PTA M resulted in the largest annual increase for milk yield. But only slightly lower responses were obtained from selection on MF$, MFP$, and NM$. The less correlated responses in milk yield were obtained from selection on PTA F, PTA P, CY$, and TPI. The smallest annual increase in milk yield was on PTA T and there was a negative response in milk yield for PTA SCS. MF$ and MFP$ were designed for these producers when the milk price was determined by milk with a fat differential and with both fat and protein differential.

Table 2-4. Genetic responses in single traits to selection from single-trait and multiple-trait indices

Selection Criteria	Expected genetic response					
	MIlk (kg)	Fat (kg)	Protein (kg)	Type (point)	SCS (score)	PL (month)
PTA M	116.05	3.40	3.43	.05	.007	.264
PTA F	78.77	4.85	2.93	.10	.001	.136
PTA P	102.74	3.78	3.75	.08	.010	.148
PTA T	17.96	1.57	1.00	.29	-.020	.231
PTA SCS	-8.66	-0.06	-0.40	.05	-.037	.037
PTA PL	26.73	0.59	0.49	.06	-.003	.314
MF$	115.37	3.54	3.45	.05	.007	.259
MFP$	110.62	3.86	3.62	.07	.007	.213
CY$	86.99	4.67	3.93	.10	.005	.118
NM	113.04	3.14	2.86	.05	.001	.383
TPI	65.38	3.60	2.73	.24	-.004	.211

Annual increase for fat yield would be the most from selection on PTA F. Most selection criteria except PTA T, PTA SCS and PTA PL could lead to reasonable increase in fat yield genetic response. Negative response in fat yield was also found selecting on PTA SCS. The correlated response in fat yield to CY$ would be higher compared with other selection criteria. The relative weight of selection emphasis in CY$ was 4 : 3 for fat yield and protein yield. The smallest annual increase in fat yield was selecting on PTA PL and negative response in fat yield was selecting on PTA SCS.

Genetic response in protein yield was obtained when CY$ was the selection criterion. The correlated genetic responses in protein to PTA P, MFP$ and MF$ were also favorable.

The smallest annual increase in protein yield was on PTA PL and the negative response in milk yield was on PTA SCS.

All selection criteria would increase SCS with much less from selection on NM$. This indicated selection criteria which would produce higher genetic responses in yield traits also lead SCS increase (.007). Selection on PTA P would increase SCS the most (.01). Genetic improvement for reduced mastitis incidence is possible by selection for fewer somatic cells count in milk from selection on PTA T and TPI. Because of the favorable correlation between udder conformation and SCS, selection on TPI, PTA T and PTA SCS could improve SCS genetically down and selection on NM$ would slow the rate of genetic increase in SCS.

Reasonable genetic response for PL could be achieved by all selection criteria. Selection on NM$ would obtain .38 month improvement per year and PTA PL and TPI would obtain .20-.26 month genetic improvement per year. High genetic correlation (.44) between milk yield and PL would result in this improvement. The results indicated that future cows will be healthier, higher producing, and more functional. Current average total herd life in U.S. was 65.2 mo for registered cows and 60.9 mo for grade cows (Short and Lawlor.1992).

All selection criteria would lead to favorable responses in linear type traits with a few exceptions including rear leg set, rump angle, fore udder attachment, udder depth and teat placement.

Table 2-5 gave correlated genetic responses in linear body frame traits by different selection criteria. All selection criteria would result in taller stature, more strength, deeper body depth and steeper foot angle. Yet, with increased milk yield from selection, it also would result in rear leg set sickle and rump angle more slope. Rump angle and rear leg side view traits in dairy cattle had been regarded as important traits. A high pin rump would affect reproductive performance because of difficult drainage through the reproductive tract and possible cause calving problems. Rear leg set relates to the durability of the legs and feet. Posty-legged cows would have too much stress on their legs, caused by an aggravation of joints. Sickle-hocked cows would have too much stress on the leg's muscles and tendons, both of which related to cow's longevity (Linear Classification Program, HFA. 1996). Short and Lawlor (1992) reported that rear leg side view was not genetically correlated with longevity and indicated that cows with a certain degree of sickliness in their rear legs stayed longer in the herd. Burke and Funk (1993) showed that intermediate curvature of rear leg was associated with longer herd life. Selection on TPI would lead to the rear leg slightly straighter (-.01) and PTA T would lead much straighter legs (-.05). Selection on TPI would lead slightly higher pin rump (-.01) and PTA T would lead to higher pin rump (-.04).

Table 2-5. Correlated genetic responses in body frame by different selection criteria

Selectction	Expected genetic response (score)							
Criteria	STA	STR	BD	DF	RA	TW	RL	FA
PTA M	.05	.01	.10	.34	.07	.06	.04	.03
PTA F	.10	.07	.16	.38	.00	.06	-.00	.04
PTA P	.10	.06	.14	.38	.04	.06	.02	.06
PTA SCS	.05	.02	.02	-.06	-.02	.06	.02	.01
PTA PL	.02	-.03	-.02	.11	.01	-.01	.00	.13
MF$	.05	.02	.10	.34	.06	.05	.03	.03
MFP$	.07	.04	.13	.37	.05	.06	.03	.04
CY$	.11	.08	.17	.40	.01	.06	.00	.05
NM	.01	.01	.06	.27	.07	.07	.03	.02
PTA T	.55	.34	.43	.46	-.05	.33	-.04	.09
TPI	.27	.20	.30	.30	-.01	.18	-.01	.08

STA : Stature (- short + tall) TW : Thirl Width (- narrow + wide)
STR : Strength (- frail + strong) RL : Real leg (- posty + sicked)
BD : Body Depth (- shallow + deep) FA : Foot Angle (- low + steep)
DF : Dairy Form (- tight + open) RA : Rump Angle (- higher pin + slope)

Table 2-6. Correlated genetic responses in udder traits by different selection criteria

Selection Criteria	FUA	RUH	RUW	UC	UD	TP
	Expected genetic response (score)					
PTA M	-.16	.08	.14	.00	-.14	-.01
PTA F	-.06	.12	.14	.04	-.08	.00
PTA P	-.10	.13	.18	.04	-.12	-.01
PTA SCS	.13	.05	.04	.02	.08	.03
PTA PL	.07	.07	.07	.04	.03	.05
MF$	-.15	.08	.14	.01	-.14	-.01
MFP$	-.13	.10	.16	.02	-.13	-.01
CY$	-.09	.14	.17	.05	-.10	.00
NM$	-.16	.04	.10	-.02	-.13	-.01
PTA T	.26	.24	.26	.13	.10	.23
TPI	.10	.22	.24	.09	.09	.14

FUA : Fore Udder Attachment (- loose + strong)
RUH : Rear Udder Height (- low + high)
RUW : Rear Udder Width (- narrow + wide)
UC : Udder Cleft (- weak + strong)
UD : Udder Depth (- below hocks +above hocks)
TP : Teat Placement (- outside + inside)

Table 2-6 shows the correlated genetic responses in udder traits by different selection criteria. Selection on yield traits, yield merits and NM$ would result in slightly larger udder, a loose fore udder attachment, higher and wider rear udder height and width, strong udder cleft and udder depth gradually below hocks. The deeper udder and more loosely attached fore udders are undesirable responses. Loosely attached fore udders usually determined how the fore udder would be carried, increased the likelihood for injury, and caused high mastitis incidence. While a degree of udder depth was necessary for capacity, a deep udder was susceptible to injury and mastitis. (Linear classification program, HFA. 1996). Selection on TPI would help to reduce or to eliminate these undesirable correlated responses.

Selection on PTA PL would also lead to favorable response in all linear type traits.

Selection on PTA PL was not a "better" selection criterion to improve type traits, because PTA PL was calculated by two components, one was direct trait using DHIA culling data and another was indirect trait using linear type data to predict PL.

When selection was on TPI, response in milk yield was reduced about 54%. Misztal (1992) used a restricted index to calculate maximum response in milk while maintaining udder depth at its current value. Using this restricted index would result in 15% decrease in genetic gain for milk yield. Standardized weights for milk yield and udder depth were 70:30, or approximately a 2:1 ratio. Rogers and McDaniel (1989) applied selection index methods by utilizing involuntary culling in an aggregate genotype to represent the composite costs of health, reproduction, and husbandry attributes. Traits considered in the index were milk yield, udder depth, teat placement, and foot angle. Simultaneous responses on increased milk yield, higher udder, closer teats, and steeper hooves were reported. Rogers (1993) included SCS information in the selection index. Index coefficients were always negative for SCS and was positive for udder depth, teat placement, and foot angle. Response on lower SCS, higher udders, and closer teat placement were reported. Standardized index indicated that milk yield should be emphasized three to four times as much as SCS, udder depth, teat placement, and foot angle combined. Udder depth and SCS was the most useful non-yield traits.

Sale of milk was the major source of income for most dairy producers. Milk yield, therefore, should receive heavy emphasis in selection programs. Selection on single-trait selection criteria such as PTA T, PTA SCS, and PTA PL might result in low responses in milk yield and should be not used as independent selection criteria. Due to their low heritabilities, they could be included in multi-trait selection criterion.

Total genetic responses in the indexed merits

The greatest return in any indexed merit was obtained by selection directly on that index. Selection on PTA of production traits and other merit indices would lead to almost as much response. Selection on PTA of SCS would result in very small positive responses in indexed merits.

Table 2-7. gave total genetic responses in the indexed merits to different selection criteria. The most improvement in an indexed merit would be from selection on its indexed value. The annual expected response achieved in indexed merit of MF and MFP to selection on MF$ were $13.78 and $13.61 per cow per year. But much higher responses were also obtained from selection on PTA M, and NM$. The less correlated responses in indexed merit of MF and MPF were obtained from selection on PTA F, PTA P, CY$, TPI.

Table 2-7. Correlated genetic responses in the indexed merits by different selection criteria

Selection	Expected genetic response ($)				
Criteria	MF	MFP	CY	NM	TPI
PTA M	13.77	13.37	12.37	12.10	35.67
PTA F	10.82	11.42	13.71	10.70	41.23
PTA P	12.64	13.33	14.45	10.70	43.40
PTA SCS	- .91	-1.10	-.79	.70	4.26
PTA PL	3.06	2.54	1.97	5.38	13.27
MF$	13.78	13.44	12.68	12.11	36.54
MFP$	13.48	13.61	12.88	12.60	40.67
CY$	11.56	12.45	14.48	11.42	44.89
NM	13.32	12.22	10.90	12.80	29.98
PTA T	2.71	3.32	4.73	5.31	43.94
TPI	8.82	9.80	11.81	9.25	58.56

The annual expected response achieved in indexed merit of CY to selection on CY$ and PTA P were $14.88 and $14.45 per cow per year. But much higher responses were also obtained from selection on PTA F, PTA M, MFP$ and MF$. The less correlated responses in indexed merit of CY were obtained from selection on TPI and NM$.

For indexed merit of NM, the most improvement in an indexed merit would be from selection on NM$ ($12.80). Much higher responses were also obtained from selection on MFP$, MF$ and PTA M. The less correlated responses were obtained from selection on CY$ PTA F, PTA P, and TPI.

For indexed merit of TPI, the most improvement in an indexed merit would be from selection on TPI ($58.56). Much higher responses were also obtained from selection on CY$, PTA T PTA P, and PTA F. The less correlated responses were obtained from selection on MF$ and PTA M.

Selection on PTA PL, PTA SCS and PTA T would lead small response in all indexed merits. Yet, selection on PTA T would lead much higher response in indexed merit of TPI ($43.94).

CONCLUSIONS AND IMPLICATIONS

The genetic response in milk yield would stay positive steadily, when any of the selection criteria from USDA and Holstein Association USA was used, as long as milk yield is included in the selection index. When milk was paid for its volume with a fat differential, or with both a fat and protein differential, selection on PTA M could result in largest response in milk yield with small difference on MF$, MFP$, and NM$. When the payment for milk was based on fat or protein yield, selection on PTA F and CY$ could get largest responses with small difference on MF$, MFP$, and NM$.

The study on correlated responses showed undesirable responses in SCS and in some linear type traits, when selection emphasis was on increasing milk yield. These undesirable responses may be caused by the health and fertility stress problems due to the increased level of milk yield. If the severity of these undesirable responses increased, the value of increased milk yields would be offset by the additional costs of handling for these undesirable responses.

The selection criteria emphasizing yield traits generally would also increase SCS in milk but to a much less extent from selection on NM$. Linear type traits such as rear leg of side view, rump angle, fore udder attachment, and udder depth would result in undesirable responses. The main breeding goal of dairy producer is to breed profitable cows, which will stay in the herd for several trouble-free lactations. If farmers' breeding goal was to breed a more profitable herd without concern about conformation, they might use independent culling levels to select AI sires with high value of these selection criteria. They should then scrutinized heavily for PTA SCS and for linear type traits such as rear leg of side view, rump angle, fore udder attachment, udder depth and teat placement. If farmers wanted to change cow conformation to meet their personal standards, selection on TPI or additional selection pressure on linear type traits after screening on yield selection criteria would be a better sire selection practice.

CHAPTER 3

PRACTICAL BREEDING SCHEMES TO MAXIMIZE GENETIC IMPROVEMENT IN A DAIRY CATTLE POPULATION OF LIMITED SIZE

ABSTRACT

A dairy cattle population of limited size merits special biological and economical considerations in designing an optimum and yet practical breeding strategy to maximize genetic gain in milk-producing ability. In this study, the geographically isolated dairy cattle population of 100,000 cows was the target population for genetic improvement, but economical factors were not considered. Various breeding schemes were designed considering practical conditions in the target population. All designed schemes involved imported germplasms from the U.S. Schemes using local genetic resources included the use of bulls from progeny test for AI services (PT/AI), the use of bulls with high pedigree merit but untested for AI and natural services (untLB/AI/NS), and the use of a MOET nucleus population to produce AI and NS bulls (MOET/AI/NS). Schemes using imported germplasms included the use of embryos to produce untested AI bulls (untFEB), or to produce AI bulls by paternal half-sib performance (STFEB) as well as the use of imported semen from the top 40% (FS40) or top 20% (FS20) U.S. proven bulls to breed local cows. Deterministic models were used to estimate the genetic level of milk producing ability in each of the consecutive 25 years when a particular breeding scheme was applied. The current genetic difference between the U.S. and the target population was considered, and the effects of genotype by environment interaction were studied.

According to cumulated genetic progress after 25 year, the breeding schemes were

ranked in descending order as STFEB, untFEB, MOET/AI/NS, FS20, FS40, untLB/AI/NS, and PT/AI. All breeding schemes surpassed the genetic gain by the current breeding scheme (CBS), except PT/AI, by 35%, 29%, 23%, 17%, 12%, and 5%, respectively. Amongst the schemes utilizing local genetic resources, MOET/AI/NS was better than CBS, PT/Al and LB/AI/NS by 19%, 40% and 13%, respectively. The schemes using imported semen exclusively were competitive with the genetic progress after 25 years being 12% (FS40) and 17% (FS20) higher than that resulted from CBS. The ranking of schemes was not affected, although the magnitude of genetic gains were, by adding a supplement of importation of 5% pregnant heifers, 5% yearling heifers, or foreign semen (FS20 or FS40) to breed 30% or 50% cows. The ranking of schemes was not influenced by genotype by environment interaction either. The use of imported embryos to produce AI bulls by paternal half-sib performance (STFEB) with a supplement of 5% imported pregnant heifers was the best scheme gaining 52% more than CBS did.

INTRODUCTION

A breeding scheme is a practice of genetic selection with application of certain reproductive technology or biotechnology. The goal of selection is to allow animals with high breeding values to be parents of the next generation. The selection intensity, accuracy of the parents' genetic evaluation, generation interval, and genetic variation will determine the genetic progress (Rendel and Robertson, 1950). The shorter the generation interval and the higher the selection intensity and selection accuracy, the more rapid would be the genetic progress. Yet, in practice, it is difficult to do all these things at once because a favorable change in one factor often made an unfavorable change in another. For example, a decrease in generation interval causes a decrease in accuracy of selection. To design breeding scheme is to balance the relationships among these factors so that genetic improvement is optimized.

The first and most important reproductive technology that had a major applied to breeding scheme in dairy cattle was Artificial Insemination (AI) with frozen semen. The introduction of Al offered excellent opportunities for the use of highly selected proven bulls. Artificial Insemination and Progeny Testing (AIPT) has been the backbone of dairy cattle improvement in developed dairy countries. This scheme identified and selected bulls with superior genetic merit for milk, fat, protein and type through their relatives and many daughters' performance. AIPT scheme could result in rates of genetic gain of 2% to 3% per year (Van Vleck, 1986). Yet, long generation intervals of progeny tested sires have limited genetic progress in AIPT scheme.

Embryo transfer (ET) technology enables females to increase family sizes and shortens the generation intervals. The use of Multiple Ovulation and Embryo Transfer (MOET) as a potential tool for genetic improvement of dairy cattle in a nucleus herd was first outlined by Nicholas and Smith (1983). In a MOET nucleus scheme, selection on young bull-dams to produce bulls could reduce generation interval and increase genetic gain by 4% to 5 %, which would be superior to those achieved in conventional breeding schemes (Dekkers and Shook, 1990).

Other reproductive technologies have been applied to breeding schemes, such as large factorial mating breeding designs with use of in vitro embryo production (IVEP). The use of physiological indicator traits and genetic marker as aids to select animals which was called Marker Assisted Selection (MAS) was also recently studied by several geneticists.

To bring genetic material of higher genetic merit into a population is another way to make genetic improvement, especially when the foreign population is genetically superior to the local population. Introducing external germplasm include importing in the form of live animals, frozen semen, and frozen embryos.

There are many dairy cattle populations of limited size in the world that operate independently either geographically or politically. Each, however, has unique features such as management system, feeds and feeding, and climatic conditions that would influence the level of milk production. Each also has made efforts to improve milk production. Target is an island located in subtropical and tropical area. A dairy industry had been developed since 1960. The demand for milk products has been increasing since 1980. However, the milk production has not met the market demand and large volume of dairy products has been imported. Milk production on the island needs to increase, since a large number of consumers prefer to have fresh milk produced locally. The dairy industry in Target also has been spending a great deal of funds and efforts in the importation of genetic material from abroad to make genetic progress. Governmental agencies, large private industries and small farmers were all involved in the massive importation effort. Today, Target had a fairly well developed breeding and recording infrastructure in place; i.e. technologies such as AI, embryo transfer and DHI. At present time, the dairy cow population is approximately 100,000 in size and will likely stay at same considering the environment and resources for dairy farming. There does not exist a long-term breeding policy for the dairy population in Target, which would accelerate and sustain genetic progress in milk yield efficiently both biologically and economically. The overall goal of this work was to seek an optimum breeding strategy tailor-made for conditions and resources in Target. The specific objectives of this study were to design alternative breeding strategies all practical under Target conditions and to use deterministic models to calculate the expected genetic change for each of the alternative breeding schemes in order to rank these proposed schemes.

MATERIALS AND METHODS

Descriptions and assumptions of the target population

Special characteristics of target population are described in chapter 1. For the breeding study, some descriptions and assumptions are listed in Table 3-1. Long calving interval (15 mo.) and high rate of involuntary cull result in only 65,000 milking cows each year. Approximately 50% of cows are on the milk recording program (DHI). Over 80% of cows were bred by AI and the rest were mated to natural service (NS) bulls. These NS bulls were of unknown genetic quality and it can be assumed that they do not contribute to genetic progress. The age structure of cow population was derived from current Target DHI database (Chang, 1997). Culling of cows was assumed to have no effect on the rate of genetic progress and results in no selection for dams to cows path. The average 305-2X-ME of milk yield was 6500kg and phenotypic SD was 800 kg respectively. The heritability of milk yield was assumed to be .3.

Assumptions for the imported germplasm

All proposed breeding schemes involve imported germplasm. More than 80 % of imported germplasm has been from Canada and the U.S. and the U.S. cattle and semen are generally favored. Therefore, for simplicity, in this study, the U.S. was assumed to be the sole source of imported genetic material. The U.S. dairy cattle population was assumed genetically superior to the target population.

Table 3-1. Descriptions and assumptions of the dairy cattle population

Size cow population	100,000	
Size milking cow population	63,000	
Recorded cow population	50,000	
Average lactation milk yield (305-2X-ME)(kg)	6,500	
Phenotypic SD in milk yield (kg)	800	
Genetic SD in milk yield (kg)	438	
Heritability of milk yield	.3	
AI services per conception	2.7	
Age at first calving (yr.)	2.2	
Calving interval (yr.)	1.3	
Parity	Age at Calving	%
1st	2.2	32
2nd	3.5	25
3rd	4.8	20
4th	6.1	15
5th +	7.4	8

The genetic difference in milk production between populations has been studied and reported by INTERBULL. Target is not a member of INTERBULL. Therefore, we assumed that a genetic superiority of 623 kg for the U.S. dairy population over Target dairy population. This was approximated by (8578-6500)*.3=623 where .3 was the heritability of milk production, 8575 was the average of milk production of the U.S. dairy population (Wiggans, 1997) and 6500 was the average of milk production of target dairy population (Chang, 1997).

Appendix A Table 1 shows the AIPL - USDA report about the genetic trend for Holstein (1998). From this report, the genetic mean for the U.S. cows was lagged behind that for the U.S. progeny-selected bulls by 400 kg (880 lb) in 1990. So the genetic superiority of 1023 kg for the US progeny tested bulls over target population was approximated. Since 1989, USDA has used an animal model to evaluate the breeding value for cows and bulls. Genetic evaluation is much more accurate than has ever been done. From 1990 to 1996 in the U.S. dairy population, the average annual genetic change was approximated to be 120kg for cows and 126kg for bulls. It was assumed that these constant annual genetic gains in milk yield for cows and bulls would be the same for 25 years in this study. Imported germplasm will be in forms of semen, embryos and live animals with different genetic levels. The notation for imported germplasm will be:

1) FS stands for the imported foreign semen selected from progeny-tested active proven bulls list according to PTA M with REL over 70% in the U.S. FS5, for example, stands for the imported semen selected from the top 5% proven bulls by PTA M.

2) FEB stands for bulls from imported foreign embryos.

3) FH stands for imports of foreign heifers. FpgH stands for imports of foreign pregnant heifers, and FylH stands for imports of foreign yearling heifers.

Current Breeding Scheme (CBS)

Current Breeding Scheme summarized the real current breeding practices in the target population.

(A). Local selected but untested bulls to mate to 20% of cows by AI:

A governmental bull station was established to raise young bulls for AI purpose. 50 second lactation cows selected from top 5% on PTA M were selected as bull-dam candidates and were contracted to mate to FS10 with 81% REL. These mating would produce 20 bull calves each year. Nine out of these 20 bull calves were purchased based on their development and health at 6 months of age and raised at bull station.

Three of nine bulls were selected based on PA (Parent Average) of PTA M and were raise to 1.5 years old. They would be used in service from 1.5 to 4.5 year of age for three years. The culling rate of untested bulls was 33%. Then 6 untested bulls were kept in AI services each year to mate to 20% of cows (2.7 doses *20,000 *1.05 =56,000 doses semen for AI. Each bull produces 10,400 doses of semen per year. (200 doses/bull/week).

(B). Imported semen mated to 60% of cows by AI:

The 170,100 doses of FS50 with 70% REL was imported per year to mate to 60% of cows in the population (2.7 doses *60, 000 cows *1.05 where 2.7 was service times per conception; 1.05 was for contingency to allow for losses from damage semen during handling semen).

(C). Natural service bulls (NS) with unknown genetic merit settled 20% of cows:

Most of herds keep natural service bulls with unknown genetic merit to sire 20% of cows. The intent of NS was to impose the reproductive efficiency. Though some of their sires were foreign, their dams were high producing cows in the herd without records, they were kept in the herds and used as NS bulls from 1.5 to 3.5 year of age for two years before culling. So they were assumed to contribute nothing to genetic improvement to the next generation.

Alternative breeding schemes

Considering practical situation in target population, three categories of alternative breeding schemes were design. Since it was unlikely in practice that all cows would be bred by AI, assumed that in each proposed breeding scheme, 20% of cows were mated to unknown genetic quality bulls by natural service. The rest 80% of cows were mated to the bulls produced from each of the proposed breeding schemes through AI. Natural service (NS) bulls would not contribute genetic progress to the population except when they were from contract matings from some of the alternative breeding schemes. In those breeding schemes, contract mating were outstanding performance cows with complete pedigree records mated to specific superior proven bulls. The young bulls from contract mating with known estimated genetic merit would be used as NS, and would contribute genetic progress to the population. These NS bulls, however, would stay as NS bulls, each herd with one NS and would only mate 30 cows a year. They could not be used extensively and could not be collected semen from them due to government regulation.

For a dairy population, the number of bulls required for AI purpose per year was given by (Lindhe, 1968):

$$\text{No. of bulls for AI} = \frac{\text{PCP} * \text{CP} * \text{SPC}}{\text{Straws collected per bull per year}}$$

Where PCP was the proportion of cow population mated to bulls by AI (80%). CP was the cow population (100,000), and SPC was the number of services per conception (2.7). In this study, if 20,800 doses of semen were collected from each progeny tested bull per year (400 doses *52 weeks), the number of bulls required for AI purpose in these dairy population was 10. For the schemes to produce untested elite bulls for target genetic improvement the rate of usage per AI bulls was reduced to 10,400 per year and the number of bulls required for AI purpose was 20.

The selection criterion for all breeding schemes is PTA M. It is estimate of genetic superiority (inferiority) that an animal will transmit to offspring. The accuracy of PTA M is reliability (REL). It is measure of amount of information in evaluation. For the young animals, Parent Average (PA) is to use to identify superior young animals early. It is calculated as one-half of his sire's PTA M plus one-half of his dam's PTA M.

The common feature of all the alternative breeding schemes in this study was that sires of bulls (SB) in breeding schemes were selected from progeny tested proven bulls in the U.S. Table 3-2(a) and 3-2(b) gave summaries of abbreviation and definition of breeding schemes. Alternative breeding schemes therefore could be divided into three categories:

1. Breeding schemes using local bull-dams mated to foreign semen with high genetic merit as bulls sires to produce selected AI or NS bulls. The related schemes were PT/AI, LB/AI/NS and MOET/AI/NS.

2. Breeding schemes using germplasms to produce AI bulls or exclusively using semen from progeny tested foreign proven bulls to mate cow population. These schemes were untFEB, STFEB, FS40, and FS20.

3. Breeding schemes in category 1 and 2 with supplements of two kinds of imports. The first one imports were importation of foreign pregnant heifers or yearling heifers to replace 5% of the cow population each year. The second imports were supplemented by importation of FS with different genetic level to mate to breed 30% or 50% cows.

Breeding schemes using local bull-dams and foreign bull-sires to produce AI bulls:

(1) Progeny tested bulls for AI (PT/AI)

The FS5 from ten foreign proven bulls with 90% REL would be used as sires of bulls. Local proven bulls were not used as sires of sons due to smaller effective population size, lower genetic level and lower accuracy than that of FS5. Eighty cows of second lactation in DHI herds with their genetic evaluation were in the top 5% would be selected as bull-dams and contract to mate to FS5. 30 bull calves would be produced. 20 bull calves were purchased based on their development and health condition and raised in the bull station. At age of 1.5, they mated all 20% of AI cow population. Each young bull had at least 100 daughters in DHI herds. Each young bull had at least 100 daughters with one lactation record and did not include any second crop daughters when they were proven. All records of these bulls' daughters were connected when doing genetic evaluation. Four out of the 20 sampling young bulls based on the rank of their progeny ranking would be selected.

From 2 years of age, semen of each young bull were collected, frozen, and stored regularly and routinely. Once 55,000 straw semen from each bull had been collected and stored and the bull was slaughtered. When the genetic merit proof of each bull become available, semen from low proof bulls were disposed. The stored frozen semen from selected proven bulls was provided to target population for regular service. They would mate to 60% of cows (20% of cows mated by testing young bulls). The generation interval was 7 years for cow-sires.

(2) Untested Local elite bulls for AI and NS (untLB/AI /NS):

Each year, 300 cows of second lactation in DHI herds with their genetic evaluation were in the top 5% would be selected as bull-dams and contract to mate to FS5. One hundred and twenty bull calves would be ranked by the estimated Parent Average for PTA M. Top 8 bull calves were purchased and raised in the bull station and the rest 100 bulls would be used as NS bulls. The rate of usage per AI bull was reduced to 10,400 per year to avoid risk. Therefore 20 untested young bulls were required to sire of 80% cows by AI. Semen collection starts at 15 months and bulls were used for four years from age of 1.5 year to 4.5 years. Each NS bull would only mate to 30 cows per year from age of 1.5 year to 3.5 year and therefore only 6 % of cows population would mate to NS bulls per year (30 cows/bull*200 bulls = 6000 cows).

Table 3-2(a). Abbreviation and definition of breeding schemes using local bull-dams

Abbreviation	Scheme description
CBS	Current Breeding Scheme. The real current breeding practices in the dairy cattle population in Target which included: 20% of cows mated to local untested elite bulls by AI 60% of cows mated to imported semen(FS50) 20% of cows mated to unknown natural service bulls
PT/AI	Official progeny tested bulls for AI. 10 progeny tested bulls were from contract mating that the imported semen of FS5 mated to top 5 % PTA M cows. Bulls were proven by their 100 daughters' performance. Semen from these bulls would be collected and stored after sampling. They would mate 80% of target cow population after proven.
untLB/AI/NS	Untested Local elite bulls for AI and NS. 20 AI bulls and 200 NS bulls were produced from the same contract mating as PT/AI. 20 AI bulls were selected by the rank of estimated Parent Average (PA) for PTA M to sire of 80% cows by AI. 200 NS bulls were in 200 herds. Each bull mated to 30 cows in the herd by NS and would contribute to 6% of target population genetic progress.
MOET/ AI/NS	Nucleus population with Multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls. 20 AI bulls and 200 NS bulls were produced from the controlled Nucleus population bred by Multiple Ovulation and Embryo Transfer (MOET) techniques. AI bulls were selected by the estimated Parent Average (PA) for PTA M to sire of 80% cows by AI. 200 NS bulls from MOET were used in 200 herds. Each bull mated to 30 cows in the herd by NS and would contribute to 6% of target population genetic progress.

Table 3-2(b). Abbreviation and definition of alternative breeding schemes using imported germplasm and their features.

Abbreviation	Scheme description
untFEB/AI	Untested bulls from imported foreign embryos for AI 10 AI untested bulls were produced from imported frozen embryos but transferred in local recipients. These embryos were from planned mating of elite cows and bulls in the exporting country and selected on the estimated Parent Average (PA) for PTA M. They would mate 80 % of target cow population.
STFEB/AI	AI Bulls from imported embryos tested by paternal half-sibs 10 AI bulls were produced from imported frozen embryos but transferred in local recipients. These embryos were from planed mating of elite cows and bulls in the exporting country. 600 doses semen of the sires of embryos would also imported at the same time so that there would be 100 paternal half-sib to the bulls. Bulls were selected by the half-sister performance in the local population.
FS40	A total of 227,000 doses frozen semen were imported each year to mate 80% target cow population. The imported semen were selected from the top 40% proven bulls list on PTA M with 70% REL from the exporting countries to sire cows.
FS20	A total of 227,000 doses frozen semen were imported each year to mate 80% target cow population. The imported semen were selected from the top 20% proven bulls list on PTA M with 70% REL from the exporting countries to sire cows.
/AI+FS40-30%	Import of FS40 to bred 30% cow population to supplement AI. FS40 semen were imported to breed 30% of the target cow population to supplement to above alternative breeding schemes.
/AI+FS20-30%	Import of FS20 to bred 30% cow population to supplement AI. FS20 semen were imported to breed 30% of the target cow population to supplement to above alternative breeding schemes.
/AI+FyrH	Importation of foreign yearling heifers as 5% of the replacement females supplemented to AI scheme. Selection for FyrH was based on the Parent Average (PA) of PTA M being greater than that of average in exporting cow population.
/AI+FpgH	Importation of foreign pregnant heifers as 5% of the replacement females supplemented to AI scheme. Selection for FyrH was based on the Parent Average (PA) of PTA M being greater than that of average in exporting cow population.

(3) Nucleus population with Multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls (MOET/AI/NS):

Four nucleus herds would constitute controlled nucleus population with 300 cows and 100 heifers in size per herd. The feeding and management of these four herds would be kept similar and controlled. They were on DHI with accurate and complete performance and pedigree records. All management and feeding practices would be recorded in all herds. The nucleus population was genetically better than the base population and would be kept open to use foreign semen to mate the cows. In each nucleus herd, top 25 heifers selected on PA of PTA M in the herd would be used as donors each year. Donors were superovulated on the individual farms, mated to FS5 with 90% REL, giving 4 embryos per flush. 400 embryos would be transferred to the recipients that were healthy heifers. For one embryo to be transfer, three synchronized heifers were needed.

So another 40 dairy farms would collaborate with the nucleus herds to provide 20 synchronized heifers for embryos transferring. With a pregnancy rate of 60 %, a calf survival rate of 85 %, and a sex ratio of 50 %, 110 bull calves and 110 female calves would be produced each year (4 embryos * .65 * .85 * .5 * 100 donors = 110). Bull calves would be ranked by the estimated Parent Average (PA) for PTA M.

Top 10 bulls from 10 families would be purchased and kept for AI and the rest 100 bulls would be sold as NS bulls.

In each nucleus herds, 130 female calves would be born each year in each nucleus herd (15 from MOET heifers, 30 from heifers, and 100 from AI cows 300*.75*.5=112). Only 300 cows and 100 female calves would be kept in the herd according to their PTA M and the rest would be sold or culled. The cows in the nucleus herds would be mated by

FS10 with 80% REL to make genetic improvement.

An initial genetic superiority in milk yield of 300 kg for the nucleus population over the target population was approximated by (7500-6500)*.3=300 where 7500 and 6500 was the average of milk production of the nucleus population and target population respectively; .3 was the heritability of milk production.

Breeding schemes using imported germplasms to produce AI bulls:

(1) Untested bulls from imported foreign embryos for AI (untFEB/AI)

The value of estimated Parent Average for PTA M of these embryos was in the top 20% PTAM of AI proven bulls. The sires of embryos were with 90% REL from progeny tested bulls and the dams were with 50% REL.

Each year, 4 young bulls would be produced every year from the imported frozen embryos. Since the embryos would be frozen embryos, success rate was assumed to be 40%. 24 frozen embryos would be imported per year (24*0.5*0.4*1.05*0.85). The bulls were raised at bull station and used as untested bulls to collect semen for AI services from age 1.5 year to 4.5 year for four years. The culling rate of bulls per year was 25%. Thus, 10 untested bulls were kept per year to collect semen to mate 80% of cows through AI. Each bull would produce 20,800 doses of semen per year (400 doses/sire/week).

(2) Bulls from imported embryos selected for AI on paternal half-sib evaluations (STFEB/AI)

Selection based on the half-sister performance had the disadvantage that the correlation between the average breeding value of half-sibs and the breeding value of the bulls was only half the correlation between the average breeding value of the progeny and the bull's breeding value. Yet, the advantage of this selection was the age of bulls at selection was reduced by 3 years. The genetic quality of imported embryos for this scheme were the same as untFEB. More 600 doses of semen of embryo's sire were imported as cow-sires, 100 half sibs to the young bulls were produced (100 half sibs * 2.7* 2*1.05 where 2 was the sex ratio). These sibs would have 1st lactation records completed when they and their brothers were 3 year of age. The accuracy of evaluation for bulls based on dam with one lactation record and 100 half-sibs. Then, selection accuracy would be increase. Four out of the 10 young bulls based on paternal half sibs test ranking would be selected. Under this situation, 56 frozen embryos would be imported per year (56 * .5 *.8 * .4 * 1.05 * .85). The bulls were raised at bull station and used as selected bulls to collect semen for AI services from age 3 year to 5 year for four years. The culling rate of proven bulls was 25%. 10 bulls with different age were kept per year to AI 80% of cows.

(3) Total reliance on foreign semen (FS)

A total of 227,000 doses frozen semen (80,000 Cows*2.7*1.05) were imported each year to mate 80% target cow population. Two schemes of semen importation were studied:

1) FS40 stands for the imported semen selected from the top 40% proven bulls list on PTA M with 70% REL from the exporting countries to sire cows.

2) FS20 stands for the imported semen selected from the top 20% proven bulls list on PTA M with 70% REL from the exporting countries to sire cows.

Individual breeding schemes supplemented by additional imports :

Two kinds of additional imports supplemented to individual breeding schemes. One is semen importation from top 20% or 40% to breed 30% or 50% of the target cow population. The second is 5% heifers imported supplement to individuals.

1) Imported foreign semen to supplement AI: AI/+FS40-30% and AI/+FS40-50% stand for importation of FS40 semen to breed 30% and 50% of the target cow population to supplement above breeding schemes respectively. AI/+FS20-30% and AI/+FS20-50% stand for importation of F20 semen to breed 30% and 50% of the target cow population to supplement above breeding schemes respectively.

2) Imported foreign heifers to supplement AI: Female animals from foreign country were imported to replace 5% of cows in target population. AI/+FyrH stands for importation of foreign yearling heifers as 5% of the replacement females supplement AI scheme. AI/+FpgH5 stands for importation of foreign pregnant heifers as 5% of the replacement females supplement AI schemes. AI/+FylH stands for importation of foreign yearling heifers as 5% of the replacement females supplement AI schemes.

Imported heifers were selected based on the Parent Average (PA) of PTA M being greater than that of average in exporting cow population. Yearling heifers were imported at their age of one year. Pregnant heifers were mated to FS50 before they were imported. When they were imported, age range of them from 20 to 24 mo with 3 to 5 mo pregnancy.

The rate of genetic change under a breeding scheme

1. Fundamentals of the rate of genetic change

Rendel and Robertson (1950) predicted genetic change based on four selection pathways: Sires to bulls (SB), Sires to cows (SC), Dams to bulls (DB), and Dams to cows (DC). The expected rate of genetic response as the result of parents selected was calculated for each pathway separately,

$G = i * r * \sigma_a / L$

Where ΔG : expected genetic response
i : selection intensity
r: accuracy of genetic evaluation
$\sigma_{additive}$: genetic standard deviation for milk yield.
L: generation interval.

Table 3-3. The selection intensity in each selection path for alternative breeding schemes

Breeding scheme (abbreviation)	Selection intensity			
	SB	DB	SC	DC
Control (C)- untAI bull(20%)	1.75	-	.33	0
FS50(60%)	-	-	.80	0
PT/AI	2.06	2.06	1.33	0
UntLB/AI/NS	2.06	2.06	1.73	0
MOET/ AI/NS				
Nucleus population	1.26	1.26	1.75	1.16
Target population	-	-	1.73	0
untFEB/AI	2.06	1.26	0	0
STFEB/AI	-	-	.6	0
FS40	-	-	.83	0
FS20	-	-	.83	0

One DE was the amount of information contributed to a parent by a standard daughter that had one record and an infinite number of management group mates. Total DE for an Animal (DE_{Animal}) was the sum of DE from PA (DE_{PA}), own yield (DE_{yield}) and progeny adjusted for mates ($DE_{prog-mate}$). Daughter Equivalent (DE) contributed to REL using Animal Model (AM) procedures by different sources of information shown as the following:

	Information available	Daughter Equivalents
Parents	Sire with70% REL and dam with 30% REL	4.7
Self	1 lactation record	4.7
Daughter	1 lactation record in one herd	1.0

$$DE_{animal} = DE_{PA} + DE_{yield} + DE_{prog - matel}$$

$$REL_{animal} = DE_{animal} / (DE_{animal} + 14)$$

REL used in this study would not include any information on second crop daughters. For example, a bull had 50 lactating daughters. REL of his parent evaluation were 90% for sire and 30% for dam. Then, REL for the bull was 79% ((4.7+50)/ (4.7+50+14) =. 79). If the progeny information (50 daughters) were not available, the REL would be 25% (4.7/ (4.7+14)=0.25). The accuracy of selection would be 0.88 and 0.5 respectively for the above example. Table 3-4 gave the accuracy of selection in each selection path for breeding schemes.

Table 3-4. The accuracy of selection in each selection path for breeding schemes

Breeding scheme (abbreviation)	Accuracy of selection			
	SB	DB	SC	DC
Control (C)- untAI (20%)	.9	.63	.5	.35-.7
FS50(60%)	-	-	.83	.35-.7
PT/AI	.95	.63	.93	.35-.7
UntLB/AI/NS	.95	.63	.5	.35-.7
MOET/ AI/NS				
Nucleus population	.9	.5	.9	.35-.7
Target population	-	-	.5	.35-.7
untFEB/AI	.9	.63	.5	.35-.7
STFEB/AI	.9	.63	.6	.35-.7
FS40	-	-	.83	.35-.7
FS20	-	-	.83	.35-.7

Prediction of genetic value of an animal with no records was usually from evaluations of its sire and dam. The accuracy of evaluation was a simple function of the accuracy of the evaluations of the two parents.

$$r = 1/2\sqrt{(REL_{Sire} + REL_{DAm})}$$

For STFEB schemes, the accuracy of evaluation for bulls was calculated using sibling and parents information. Because no Daughter Equivalents for sibling information, the accuracy of evaluation for bulls was calculated using selection index theory.

(c). Generation interval (L): L was the average age of the parents when their offspring were born. The following were the calculation of L. Table 3-5 showed the generation interval in each selection path for breeding schemes

1) SC: For the alternative breeding schemes involving bull selection, untested bulls mate to cow population from 1.5 to 4.5 years and the generation intervals were 3 to 6 years. For the progeny tested bulls, his daughters would be born at his age of year 3. His daughters finished their first lactation at his age of year *6*. For local proven bulls, they sire to cows and his offspring born at his age of year 7 (L_{SC} =7). For imported semen as sire of cows, they were imported at their age of year 7 and mated to cows and their daughters were born at his age of year8 (L_{SC} =8).

2) DB: For the alternative breeding schemes involving bull-dam selection, a cow must have at least one own record in her genetic evaluation to be selected as a bull-dam. This evaluation would be obtained at the beginning of her second lactation. The contract mating would take place during her second lactation. Her son would be born at her third lactation calving and her age at that time was 5 years old (L_{DB} =5).

3) SB: For the alternative breeding schemes involving bull-sire selection, imported semen of foreign proven sire mated to bull-dams at their age of 7. Their sons born at their

age of 8 (L_{SB} =8).

4) DC: The generation intervals for DC path would be 3 to 8 year at their lactation calving for all breeding schemes.

Table 3-5. The generation interval in each selection path for breeding schemes

Breeding scheme (abbreviation)	Generation interval (years)			
	SB	DB	SC	DC
Control (C)- untAI (20%)	9	5	3-5	3-8
FS50(60%)	-	-	8	3-8
PT/AI	9	5	7	3-8
UntLB/AI/NS	9	5	3-5	3-8
MOET/ AI/NS				
Nucleus population	9	3	9	3-8
Target population	-	-	3-5	3-8
untFEB/AI	9	5	3-5	3-8
STFEB/AI	9	5	4-5	3-8
FS40	-	-	9	3-8
FS20	-	-	9	3~8

(d). Additive genetic standard deviation (σ_a)

Additive genetic standard deviation (σ_a) refers to the variability of breeding values within a population for milk yield. It was somewhat difficult to change. Bulmer (1971) showed that the additive genetic variation was temporarily reduced by the selection of parents and ancestors, but regenerates quickly when selection was relaxed.

2. Calculations of genetic progress

The annual genetic progress under each of the breeding schemes over 25 years was evaluated using deterministic models. The generations were considered overlapping because at any given time, cows were of different ages and the selection of parents was a continuous process. Under this situation, animals of different age classes were regarded as coming from different distributions of genetic merits with different means and variances due to genetic trend.

The time-dependent population inventory approach presented in Ducrocq and Quaas (1988) was used (Method DQ). Method DQ approach was suitable for predicting response for a dynamic selection system. To calculate the genetic progress in the cow population under a particular breeding scheme the first step was to identify the proportion of different age cow groups in the population at year *t*, each group with the same age. The genetic progress of the cow population for each breeding scheme was weighted genetic merit mean for cows with different ages. Weighting was on the proportion of the cows' age group. The genetic merit mean for newborn animals could be obtained by the averaging genetic merits of their parents. The average genetic merit of their parents was the selection differential of their parents plus genetic mean of the animals at the birth year of their parent.

The Method DQ also allowed the use of local or imported germplasm in each of the selection paths. In calculating genetic merit for imported germplasm, the initial genetic difference between the exporting and importing populations, the genetic trend in exporting, and the different levels of genotype by environment interaction were considered. The reduction of additive genetic variance due to selection (Bulmer effect) and inbreeding depression was not considered, because all breeding schemes in this study involved importation of germplasm from foreign country.

At year *t*, the genetic merit of the newborn animals was determined by the genetic merit of the parents selected at year (*t* -L). The genetic merit of the parents selected at year (*t* -L) was calculated for each pathway separately as following equation:

$$m_{(t\text{-L})} = \mu_{(t\text{-L})} + \Delta G_{(t\text{-L})} \qquad [3.2]$$

Where $m_{(t\text{-L})}$: the genetic merit of parents selected at year (t-L) and produced offspring at year t.

L: the age of the parents when offspring was born at year t.

$\mu_{(t\text{-L})}$: the genetic merit mean of animals at year (t -L).

$\Delta G_{(t\text{-L})}$: selection response of the selected parents at year (t -L).

The genetic merit of an animal born at year t was the average genetic merit of the parent :

$$(m_{S(t-L_S)} + m_{D(t-L_D)}) / 2 \qquad [3.3]$$

Where $m_{S(t-L_S)}$ and $m_{D(t-L_D)}$: the genetic merit of sire selected at year (t-L_S) and the genetic merit of dam selected at year (t-L_D) respectively.

$$m_{S(t-L_S)} = \mu_{S(t-L_S)} + \Delta G_{S(t-LS)}$$

$$m_{D(t-LD)} = \mu_{D(t-LD)} + \Delta G_{D(t-L_D)}$$

The average genetic level for newborn animals (bulls or cows) at year t :

$$M_{c(t)} = (\Sigma\alpha_{SC(t-L_{SC})} * m_{SC(t-L_{SC})} + \Sigma\alpha_{DC(t-L_{DC})} * m_{DC(t-L_{DC})}) / 2 \qquad [3.4]$$

$$M_{B(t)} = (\Sigma\alpha_{SB(t-L_{SB})} * m_{SB(t-L_{SB})} + \Sigma\alpha_{DB(t-L_{DB})} * m_{DB(t-L_{DB})}) / 2$$

where μ_C (t) and $\mu_{B(t)}$: the average genetic level of new born female animals and male animals at year t,

$m_{SC(t-L_S)}$ and $m_{SB(t-L_{SB})}$: genetic merit of sire selected at year (t - L_{SC}) and at year (t - L_{SB}) to be SC and SB.

L_{SC} , L_{DC} ,L_{SB} ,and L_{DB} : the age of SC and DC as well as SB and DB at year t when their offspring were born.

α_{SC}: the proportion of sires of cows with different age at year t.

α_{DC}: the proportion of dams of cows with different age at year t.

For the all schemes, selection and mating started year *0*. Bulls were born and selected at year *1*. For the untested young bulls, they would mate to target cow population at year *3* when they were 2 years of age. In PT/AI, before year7, assume all AI cow population were bred by young sampling bulls which age were 2 to 3 years. From year 7, first group of proven bulls at their age of 7 was bred to 60% of AI cow population and the young sampling bulls mate to the rest of 20% AI cows population. From year *4* on for untested bulls and from year *8* on for progeny tested bulls, the bulls produced from each breeding scheme mated 80% of target cow population.

3. Calculating the genetic progress of cow population at year *t*

$$\Delta g_c(t) = \Sigma \omega(i, t) * M_{C(t-i)} \qquad [3.5]$$

where $\Delta g_c(t)$: the genetic progress of cow population at year *t*.
$\omega(i, t)$: the proportion of the different cow age groups (i= 2,3,4,5,6,7) at year *t*.

The equation [3.5] meant the genetic progress of the cow population at year *t* for each breeding scheme was weighted genetic levels for cow groups with different ages at year *t* compared with that at year *0* which was set up to 0.

Genotype by environment interaction between populations

When a breeding scheme was based on imports of genetic material from the foreign country, genotype by environment interaction was considered. The product-moment correlation between breeding value of sires estimated in the U.S. and in target population could be used as a measure of genotype by environment interaction (Petersen, 1975; Danell, 1982). Genetic progress should be adjusted for genotype by environment interaction and it could be regarded as a correlated response (Falconer, 1989). The correlated response for germplasms selected in the U.S. and used in Target would be:

$$\Delta G_{Target} = i_{US} * r_{US} * \sigma_{a\ Target} * r_{g\ US,\ Target}$$

ΔG_{Target}: selection response for germplasms selected in the U.S.and responded in Target
i_{US}: the selection intensity for the imported genetic material in the US;
r_{US} : the selection accuracy of genetic evaluation in the US;

$\sigma_{a\ Target}$: the additive genetic standard deviation for milk yield in Target;

$r_{g\ US,\ Target}$: the genetic correlation between the US and Target

Up to now, BLUP genetic evaluation system in Target had not been established. Information on genotype by environment interaction (G X E) was not available. So the value for the genetic correlation between the two countries was assumed to be .5 and .9 respectively to investigate the effect of r_g on the ranking of breeding schemes. The genetic correlation between nucleus population and base population was assumed to be 1.0 for the MOET nucleus scheme. That r_g assumed to be .9 meant there was little GXE while r_g were .7 and .5 meant there existed moderate to considerable GXE respectively.

RESULTS AND DISCUSSIONS

Estimated genetic trend for the exporting country

The initial difference in genetic merit mean between the target cow population and the U.S. cows population and the US progeny tested bulls was assumed to be 623 kg and 1003 kg, respectively. The average annual genetic gain was assumed to be 120kg and 126kg for the U.S. cow population and the U.S. progeny tested proven bulls population, respectively. Based on these assumptions, Table 3-6 showed the trend in the U.S. dairy populations and genetic merit of gernplasm imported from the US into target population which included FS50, imported heifers and new born females from imported pregnant heifers.

Table 3-6. Assumed genetic trend in the U.S. dairy populations and genetic merit of gernplasm imported from the US into target population

Year	The U.S. pop.		Germplasm imported into target pop.		
	AI bulls	Cows	FS50	Imported heifers	New born females from imported pregnant heifers
-3	645	263	223	385	-
-2	771	383	349	505	-
-1	897	503	475	625	-
0	1023	623	601	745	427
5	1653	1223	1231	1345	1042
10	2283	1823	1861	1945	1657
15	2913	2423	2491	2545	2272
20	3543	3023	3121	3145	2887
25	4173	3623	3651	3740	3502

Estimated genetic levels and genetic progress

Table 3-7 and Table 3-8 showed the results at specific year for CBS and nucleus population. The assumption of genetic merit mean in milk yield at year *0* was set up 0. All selection and importation started at year *0*. The progress of the genetic merit in milk yield of new born males from contract mating in CBS, PT/AI, LB/AI/NS, MOET/AI/NS, unt FEB, and STFEB started at year *1*. These bulls started to mate to the cow population at year *3*. So the progress of genetic merit in milk yield of new born females started at year *4* and there was no genetic response on the cow population until year *7* when these female offspring calved and milking. The response was unstable in the earlier period until the change of the number of cows and bulls with different ages in the population were stable. Figure 3-1 gave the trends of estimated genetic progress of target cow population over 25 years under proposed breeding schemes. The existence of the time lag between the operation of selection and their effect on the cow population were nicely visualized. The trends of genetic levels and genetic progress were non-linear over 25 years.

Table 3-7. Estimated annual genetic progress of breeding stock and the target cow population for the Current Breeding Scheme (CBS)

Year	Genetic merit mean of breeding stock at birth			Genetic progress
	FS50	untAI Bulls	Females	In target pop.
0	223	0	0	0
1	349	542	131	0
4	727	731	344	10
7	1105	1009	609	125
15	2113	1878	1449	702
20	2743	2464	2022	1132
25	3373	3065	2613	1589

Table 3-8 Estimated genetic progress in the nucleus population for the MOET/AI/NS

Year	Genetic merit mean of breeding stock at birth		Genetic progress
	AI bulls (FS20)	Females	nucleus population
0	0	300	300
1	625	400	300
4	1003	589	427
7	1381	810	617
15	2389	1766	1551
20	3019	2380	2157
25	3649	3002	2774

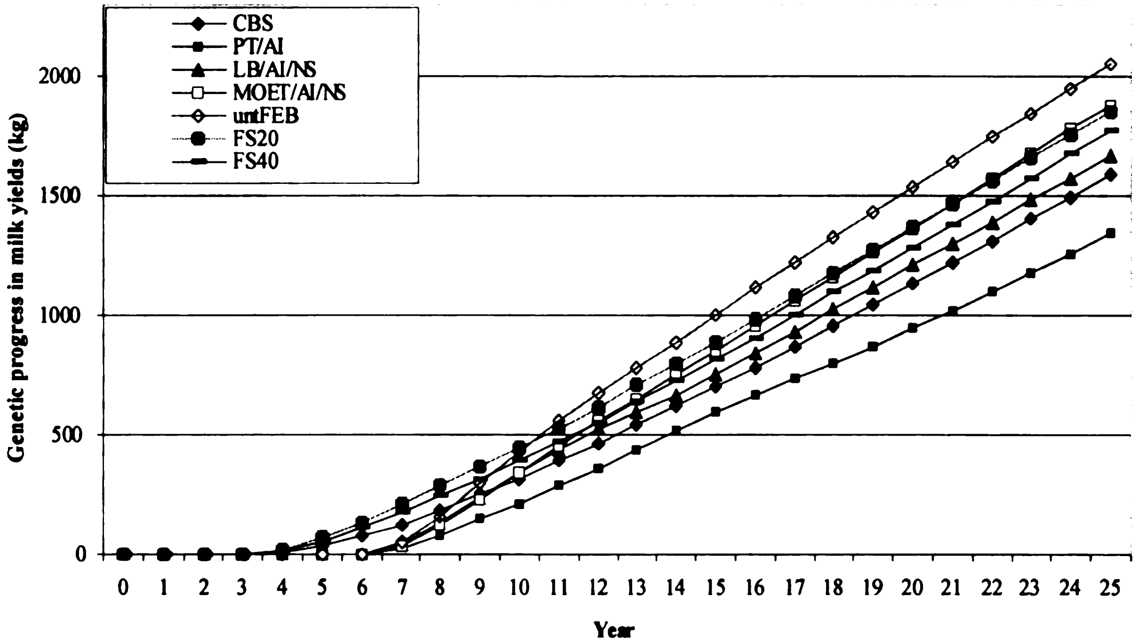


Figure 3-1. Estimated trend of genetic progress of the target cow population under proposed breeding schemes over 25 years

For FS40 and FS20 schemes, the semen were imported at year *0* and mated to the cow population at the same year. The bulls were born 8 year ago and completed first crop progeny test in the US. The progress of genetic merit of females in the population started at year *1* and genetic progress of cow population started at year 4, which was 3 years earlier than that of others proposed breeding.

Comparisons among proposed breeding schemes

The rank on rate of genetic progress after 25 year for the breeding schemes was STFEB, untFEB, MOET/AI/NS, FS20, FS40, untLB/AI/NS, CBS and PT/AI with 2141, 2053,1948,1856, 1771,1667, 1588, and 1339 kg/cow, respectively. All proposed breeding schemes, except PT/AI scheme, were superior over CBS by 35%, 29%, 23%, 17%, 12%, and 5%, respectively (Table 3-9). The rank on genetic progress after 25 year for proposed breeding schemes supplemented by importation of 5% foreign pregnant heifers or 5% foreign yearling heifers remained the same as expected but influenced on the magnitude of the genetic progress.

For the proposed breeding schemes with supplement of importation of 5% foreign pregnant heifers, the genetic progress at year 25 was higher than that of individual breeding scheme without supplement by from 364 kg (PT/AI) to 287 kg (STFEB). For the individual breeding schemes with supplement of importation of 5% foreign yearling heifers, the genetic progress at year 25 was higher than that of individual breeding scheme without supplement by from 319 kg (PT/AI) to 261 kg (STFEB). The genetic progress after 25 years for the supplement practice of importation of 5% foreign pregnant heifers was higher than that for the importation of 5% foreign yearling heifers by from 55kg (PT/AI) and 26 kg (STFEB).

Table 3-10 showed genetic progress after 25 years for individual breeding schemes or for individual breeding scheme combined with importation of yearling or pregnant heifers with supplement of FS40 to breed 30% or 50%. PT/AI and LB/AI/NS combined with importation of pregnant heifers with supplement of FS20 to breed 50% cows would result in higher genetic improvement than that of adopting PT/AI or LB/AI/NS without supplement. But for the individual breeding scheme of MOET/AI/NS, untFEB/AI and STFEB/AI/NS combined with importation of yearling or pregnant heifers with supplement of FS20 to breed 30% or 50%, the genetic progress after 25 years would not result in higher genetic progress than that of adopting MOET/AI/NS, untFEB/AI and STFEB/AI/NS without supplement.

Table 3-9. The estimated genetic progress of target population at year 25 under different breeding schemes

Breeding scheme (abbreviation)	Genetic mean at year 25 (kg)	Difference from CBS (kg)	% of the CBS	Rank
Control (C)	1588	0	1.00	7
PT/AI	1339	-249	0.84	8
PT/AI +FpgH	1703	115	1.07	
PT/AI +FyrH	1658	70	1.04	
UntLB/AI/NS	1667	79	1.05	5
UntLB/AI/NS+FpgH	2031	443	1.28	
UntLB/AI/NS+FyrH	1989	401	1.25	
MOET/ AI/NS	1882	294	1.19	3
MOET/ AI/NS+FpgH	2226	638	1.40	
MOET/ AI/NS+FyrH	2190	602	1.38	
untFEB/AI	2053	465	1.29	2
untFEB/AI+FpgH	2348	760	1.48	
untFEB/AI+FyrH	2321	733	1.46	
STFEB/AI	2141	553	1.35	1
STFEB/AI+FpgH	2428	840	1.53	
STFEB/AI+FyrH	2402	814	1.51	
FS40	1771	183	1.12	5
FS40+FpgH	2095	507	1.32	
FS40+FyrH	2061	473	1.30	
FS20	1856	268	1.17	4
FS20+FpgH	2171	583	1.37	
FS20+FyrH	2139	551	1.35	

[1]CBS= Current Breeding Scheme, PT/AI= Progeny Tested bulls for AI, untLB/AI/NS= Untested Local elite bulls for AI and NS, MOET/AI/NS= Nucleus population with Multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls, untFEB= Untested bulls from imported foreign embryos for AI, STFEB= AI Bulls from imported embryos tested by paternal half-sibs, FS40= The imported semen selected from the top 40% proven bulls in U.S. FS20= The imported semen selected from the top 20% proven bulls in U.S. +FpgH= Importation of foreign pregnant heifers as the replacement females supplement to AI scheme. +FylH= Importation of foreign yearling heifers as the replacement females supplement to AI scheme.

MOET/AI/NS was the best strategy of those using local germplasm. LB/AI/NS ranked the second. At year *25*, the estimated genetic progresses of the commercial cow population for these two schemes were 1882 and 1667 kg respectively and higher 19 % and 5 % than that of CBS. Table 3-9 showed the genetic change over 25 years in the nuclear population. MOET/AI/NS scheme had an advantage of an initial genetic lift from the founder stock of the nucleus herd. In these two schemes, 100 NS bulls were produced by contract mating and utilized MOET each year and 200 bulls were in natural service to mate 6% of cow population. The genetic progress at year *25* for the STFEB and FEB strategy were 2246 kg and 2053 kg respectively, STFEB scheme was better than the untFEB by 9.4%. Yet, there were more 6000 straws of SB semen imported which were sires of embryos and needed economic efficiency analysis to determined if the genetic difference between STFEB and FEB lead to greater economic benefits.

Table 3-10. Genetic improvement in milk yield (kg) at year *25* for the alternative breeding schemes with supplement of FS40 or FS20 to breed 30% or 50% cows.

Breeding scheme (abbreviation)	FS 0%	FS40 30%	FS40 50%	FS20 30%	FS20 50%
CBS	1588				
PT/AI	1338	1484	1573	1515	1622
PT/AI +FpgH	1702	1835	1916	1862	1960
PT/AI +FyrH	1658	1794	1877	1822	1922
UntLB/AI/NS	1667	1743	1788	1777	1841
UntLB/AI/NS+FpgH	2030	2100	2140	2131	2189
UntLB/AI/NS+FyrH	1989	2060	2102	2092	2151
MOET/ AI/NS	1948	1928	1915	1956	1960
MOET/ AI/NS+FpgH	2286	2268	2256	2292	2296
MOET/ AI/NS+FyrH	2251	2233	2220	2258	2262
UntFEB/AI	2053	1968	1912	1994	1954
untFEB/AI+FpgH	2348	2272	2221	2295	2259
untFEB/AI+FyrH	2321	2243	2191	2266	2230
STFEB/AI	2141	2030	1956	2055	1998
STFEB/AI+FpgH	2427	2328	2261	2350	2299
STFEB/AI+FyrH	2402	2300	2231	2323	2270

Importation of the different genetic quality semen of foreign bulls used in Target from the top 40% to the top 20% does not had very large difference on the genetic progress at year *25* (1771kg vs 1856 kg). This was because the differences in the selection response among the bull percentile groups were not large (Table 3-11).

PT/AI breeding scheme was the only one that the genetic progress at year *25* was lower that that of CBS. In PT/AI scheme, sampling young bulls were assumed to mate to 80 % of cow population from year *3* to year *6*. Newborn females would benefit from genetic contribution from these sampling young bulls since year *4*. Progeny tested AI bulls were proven at year *6*. The offspring of these progeny tested proven bulls would be born at year *7* and would contribute genetic progress to the cow population at year *10*. Due to long generation interval and lower selection intensity (20%) for the SC, the genetic progress of cow population was very slow and realized much later than that of other proposed schemes. At year *25*, only 1339kg improvement was obtained and was lower 16% than that of CBS. Progeny testing and artificial insemination has continued to be the backbone of dairy cattle improvement and currently operate in most developed countries though it was a time consuming and expensive operation task. Modern PT/AI schemes lead to substantially higher estimates of annual genetic change than previously hypothesized and should reflect selection intensity increases as well as shortened generation intervals. Yet, these parameters which affect genetic progress were difficult to achieve in practice for target population breeding schemes involving imports.

Most of bulls produced from alternative breeding schemes were untested. Superior young animals needed to be identified. Parent Average (PA) has been utilized for this purpose for many years. Though parent average was a good predictor of the bull's eventual proof, some young sires would come through with proofs below their parent average, while others would come through with higher proofs. The net result was that the average proofs for a group of bulls was usually quite close to the overall average of the bulls' parents. Overall, little difference existed between the genetic merit of young sires and the genetic merit of the Active Al bulls that were available at the same time the progeny-tested bulls were sampled (Powell and Norman, 1989). The weakness of the PA as a predictor was the accuracy of predicted transmitting abilities (PTA) for bull-dams. Though the implementation of the animal model greatly increased the accuracy of cow PTA, there was still a tendency of overestimating PTA for bull-dams (Ferris et al. 1991, Graham et al, 1991, Mao et al, 1991, Uimari et al. 1992). If bull dams could be reliably identified, the use of untested young bulls could be more favorable than progeny testing (Smith and Burnside, 1990). Thompson and Freeman (1972) found that the use of untested sons of progeny bulls gave rapid genetic gain in small population.

Hunt et al. (1974) compared estimates of genetic gain from progeny testing programs with estimates when the same population was bred only to young bulls except for contract mating. All young bulls gave similar rates of genetic progress to progeny testing schemes for the smallest cow population. The all young bulls gave comparable results to progeny testing when a low percent of the population was recorded and a low percent of recorded cows were bred to young test bulls. The numbers of young bulls required to achieve the rates of genetic gain shown were high. Target dairy population was limited size with 100,000 cows. The untested bulls produced from breeding schemes would use as a group with confidence for regular service to breed cows, and if bull-dams could be reliably identified, the optimum breeding scheme still could be identified with untested young bulls.

FS40 and FS20 could make higher and faster genetic gains because they were from dairy populations with a genetic mean higher than that of Target. These two schemes started to contribute genetic progress at year 4 while other schemes started at year 7. At year 7, these two schemes had contributed genetic progress by 173 kg and 209 kg respectively. It showed that adopting semen imports strategy in the earlier period and later switching to a local selection program should contribute more genetic progress. Semen imports strategy in the earlier period upgraded the domestic stock and then further improved the new domestic stock through local selection programs. Moreover, imports would increase genetic variation in the population, which would ensure the success of a well-run progeny testing scheme.

Table 3-11. The genetic change in each selection path for breeding schemes

Breeding scheme (abbreviation)	Genetic change			
	SB	DB	SC	DC
Control (C)- untAI (20%)	482	459	232	-
FS50(60%)	-	-	208	-
PT/AI	600	569	538	-
UntLB/AI/NS	600	569	378	-
MOET/ AI/NS		-	-	-
Nucleus population	600	275	484	253
Target population	-	-	378	-
untFEB/AI	-	-	214	-
STFEB/AI	-	-	219	-
FS40	-	-	245	-
FS20	-	-	356	-

Selection of parents gives rise to a temporary disequilibrium with less genetic variation for selection among offspring (Bulmer, 1971). For this study we assumed that these two populations had been under continuous selection for milk yield and had reached selection equilibrium. Therefore the genetic parameters used already partly include the reduction due to the Bulmer effect. If the assumption does not hold the Bulmer effect, it would reduce the genetic mean in practice and the population mean estimated. In progeny testing scheme, the Bulmer effect would reduce response by 21% and genetic variance by 27% (Meyer and Smith, 1990). The reduction in genetic variance due to selection was likely to be less in MOET schemes because of less accurate and less intense selection than progeny testing. In Jeon et al. (1990), the estimated reduction in genetic variance in MOET schemes was 17%. However, these values were dependent on the parameters used. Keeping the population open to introduce germplasm from the exporting country would result in higher genetic means and reduce the effects of inbreeding (Hodges, 1991). When calculating the genetic merit mean of new born animals, we didn't consider the Bulmer effect.

The effect of genotype by environment interaction

The effect of genotype by environment interaction on the genetic progress at year 25 when the initial difference between the US and Target population was 603kg was showed in Table 3-12. Because the initial genetic mean difference between two populations was a constant and selection response were low for the breeding schemes in this study, the ranking of schemes did not change when the r_g increases from .5 to .9. But it influenced the magnitude of the genetic level of bulls at birth and the genetic progress for a breeding scheme.

By importing foreign germplasm form North America to a subtropical area, genotype by environment interaction had been shown not to be important amongst temperate countries (Petersen, 1975; Garabano et al., 1989; Sieber and Powell, 1989). Yet, the results reported for GXE interactions between temperate and tropical countries were inconsistent and inconclusive possibly due to limited sets of data available. In McDowell et al. (1976) report, the genetic correlation estimate for milk production between Mexico and the USA was high (.86) whereas in Abubakar et al. (1987) report, it was moderate (.51). The lowest genetic correlation in performance found in the literature was .08, between Sri Lanka and Denmark (Buvanendran and Petersen, 1980). In Chauhan (1983), the genetic correlation between Denmark and India was .11 while that between USA and India was .7. These figures showed serious GXE interaction. INTERBULL estimated of genetic correlations among countries. Estimates would normally range from .86 to .89 between two North Hemisphere countries and from .75 to .78 between a North and a South Hemisphere country. The interaction between the genetic correlation of countries and the initial genetic difference between the importing and the exporting counties also influenced ranking of the schemes. Mpofu (1993) reported that when the initial genetic difference was low and the r_g between the two countries was high (1.0), genetic progress was faster for all schemes both based on imports and on local selection. But when the initial genetic difference was high with a low genetic correlation, it meant that the genetic correlation between countries should be given more weight than the initial genetic difference between countries when choosing the import countries.

Table 3-12. The effect of different genotype by environment interaction (r_g) on genetic improvement of milk yield for the proposed breeding schemes at year *25*

Breeding scheme (abbreviation)	Genotype by environment interaction		
	$r_g = .5$	$r_g = .7$	$r_g = .9$
Control (C)	1539	1588	1638
PT/AI	1260	1339	1416
PT/AI +FpgH	1626	1702	1719
PT/AI +FyrH	1581	1658	1734
UntLB/AI/NS	1577	1667	1757
UntLB/AI/NS+FpgH	1943	2030	2118
UntLB/AI/NS+FyrH	1901	1989	2077
MOET/ AI/NS	1773	1881	1990
MOET/ AI/NS+FpgH	2121	2225	2330
MOET/ AI/NS+FyrH	2084	2189	2295
untFEB/AI	2006	2053	2099
untFEB/AI+FpgH	2301	2438	2395
untFEB/AI+FyrH	2274	2321	2368
STFEB/AI	2067	2141	2215
STFEB/AI+FpgH	2355	2427	2500
STFEB/AI+FyrH	2329	2402	2475
FS40	1717	1771	1825
FS40+FpgH	2040	2095	2149
FS40+FyrH	2007	2061	2115
FS20	1778	1856	1934
FS20+FpgH	2095	2171	2247
FS20+FyrH	2062	2139	2215

CONCLUSIONS AND IMPLICATIONS

There are several breeding schemes used in different dairy populations in the world. This study studied 7 alternative breeding strategies designed for practical use in the target population. Because all breeding schemes involved importation of foreign germplasm, inbreeding depression and genetic drift, which would have otherwise influenced genetic changes over generations, were ignored.

Among the designed breeding schemes, STFEB scheme with supplement of importing 5% pregnant heifers had the highest cumulative genetic gain in milk yield at year 25. In this scheme, imported elite embryos produced bulls as SC and imported 6000 straws of semen from sires of embryos, which was FS10, were also as SC to mate cows in target to produce paternal half-sibs to test the bulls produced from embryos. Both bulls from embryos and bulls of sires of embryos contributed genetic progress to the population. Because frozen embryos to produced AI bulls and semen of SB were imported from a foreign source, large amount of importation costs imposed on this scheme. Economic efficiency needed to be evaluated to determine if it was an optimum-breeding scheme for target dairy population. The second optimum scheme was untFEB. This scheme only imported enough embryos to produce required AI bulls.

Amongst the schemes utilizing local resources, MOET/AI/NS was better than CBS, PT/Al and LB/AI/NS respectively. Poor reproductive efficiency of dairy cows was an obstacle to genetic improvement because of long generation interval. MOET/AI/NS and LB/AI/NS produced AI and NS bulls. These two schemes were special tailor-made breeding schemes for target population situation. NS bulls produced from MOET or contract matings with known genetic merit and would contribute genetic progress to the population and improve reproductive efficiency. These NS bulls, however, would only stay as NS bulls for two years in herd, each herd only with one NS bull. Each bull would only mate 30 cows a year in a herd. Genetic contribution from them to the population was only 6%. To produce more NS bulls with known genetic merit and AI bulls with high genetic merit, MOET and IVFP (In Vitro Fertilization Production) could make it and would be very important technologies applied to breeding scheme in Target in future study.

Total reliance on foreign semen with the genetic progress at 25 years were higher than that resulted from CBS. FS40 and FS20 could make higher and faster genetic gains because they were from dairy populations with a genetic mean higher than that of target population. The genetic progress adopting FS20 or FS40 schemes showed that the genes flow from the foreign population to the importing population was faster in SC path than in SB path.

Scheme PT/AI has been standard in most developed countries. However, in this study, PT/AI was the only scheme, of which genetic gain was lower than that of CBS. Lower selection intensity and longer generation interval were the primary reasons.

Ranking of schemes was not affected by the inclusion of a supplement of importation of either 5% pregnant heifers or 5% yearling heifers, or a supplement of FS20 or FS40 to breed 30% or 50% cows. However, the supplements did affect the magnitude of all genetic gains after 25 years.

In this study, PTA M was the sole selection criterion for all breeding schemes. Other traits such as stress resistant traits in fertility, calving ease, mastitis resistance, and other health traits perhaps need to be considered in breeding goals as well. However, the development of a total merit index and the establishment of an overall breeding goal are beyond the scope of this study.

CHAPTER 4

ECONOMIC EFFICIENCY OF ALTERNATIVE BREEDING SCHEMES FOR A DAIRY CATTLE POPULATION OF LIMITED SIZE

ABSTRACT

The geographically isolated dairy cattle population of 100,000 in Taiwan population was the target population for genetic improvement. Eight practical alternative breeding schemes and schemes with supplement of additional imported germplasm were designed. In the previous Chapter, these schemes were ranked with respect to their rates of genetic progress. This study attempted to rank the same schemes for their economic efficiency. For each of the schemes, appropriate governmental agencies were expected to bear all costs for the establishment and maintenance of its infrastructure and operation. Farmers would be expected to pay the costs for semen, AI, imported heifers, as well as increased costs of feeds, health and fertility problems due to increased milk production.

The economic efficiency for a breeding scheme was calculated as the Net Present Value of its accumulated benefit over a 25 years time horizon. The ranking of the designed breeding schemes based on their economic efficiency was different from that based on their rates of genetic progress. All schemes involved the importation of pregnant or yearling heifers resulted in relatively high rates of genetic improvement, but were not efficient economically. The economic efficiency ranking, in descending order, were STFEB, FEB, MOET/AI/NS, LB/AI/NS, FS40, PT/AI and, FS20. All of these alternative breeding schemes with the exception of the last two, surpassed the current breeding scheme (CBS) in economic efficiency by 7%, 6%, 5%, 3%, and 1%, respectively.

Amongst the schemes utilizing local resources, MOET/AI/NS was better than CBS, PT/Al and LB/AI/NS by 5%, 6% and 2%, respectively. Amongst all the breeding schemes designed, the use of imported embryos to produce AI bulls tested by half-sib performance (STFEB) was the best in terms of economic efficiency, as well as, as shown earlier in the previous Chapter, in terms of the rate of genetic progress. Different levels of genotype by environment interaction affected the magnitude of estimated economic benefits but did not affect the ranking of these schemes.

INTRODUCTION

Milk production is the major source of income for a typical dairy cattle production system accounting for 80 to 90% of the gross income. Because milk yield is reasonably heritable, it should be therefore the primary selection goal for all dairymen. The rate of genetic progress achieved dependents upon the sources of sires and dams and the breeding scheme used. Early investigations on identifying an optimum-breeding was giving maximum genetic progress. (Rendel and Robertson,1950). Lindhe (1968) and Oltenacu & Young (1974) showed that it was not sufficient to characterize a breeding scheme merely in terms of genetic gains. Miller (1977) reviewed economic studies of selection programs for artificial insemination and concluded that there was a diminishing increase in rates of genetic gain with increasing costs of a breeding program. More recently, the trend had been to follow up genetic evaluations with economic evaluations (Ruane and Smizh, 1989; Dekkers and Shook, 1990; Mpofu etal., 1993). Dekkers and shook (1990) presented genetic and economic consequences of hybrid nucleus breeding schemes for AI firm operating under circumstances in the US Holstein population. Open adult schemes increased present value of returns from 20 years of selection by 10% to 20%. Relative gains in returns to progeny-tested bulls increased from 8 to 16% for the first 4 years of selection to 46 to 63% for the first 20 yr. They also concluded that large adult MOET scheme might not be profitable to run.

Costs and returns for a breeding scheme accumulated over time and were realized over different periods. They must be expressed in comparable time units. The usual method of comparison was through discounting which future costs and benefits were transformed to current value. The economic efficiency of a breeding scheme was best measured over a long but finite period. Gains obtained early were of greater monetary value than those obtained later in the scheme (Smith, 1981).

An optimum breeding scheme would need to be the one that gives high rate of genetic progress, but at reasonable costs and maximum benefits to the dairy industry. Therefore, the specific objectives of this study were to use Net Present Value (NPV) to determine the economic benefits and costs of each of the proposed breeding schemes in Chapter 3, and to re-rank the same schemes based on their economic efficiency.

METERALS AND METHODS

Current breeding scheme and proposed alternative breeding schemes

Current Breeding Scheme summarized the real current breeding practices in target population. It includes 20% of cows mated to local selected but untested bulls by AI service, 60% of cows mated to imported semen by AI, and 20% of cows mated to unknown quality bulls by natural service. The genetic change calculated for CBS was used as the base for comparisons with other alternative breeding schemes.

Seven proposed alternative breeding schemes and different proportion (30% and 50%) of imported foreign semen combined with alternative schemes and 5% of import heifers supplemented to AI were studied.

(1) Official progeny tested bulls for AI (PT/AI)

10 progeny tested bulls were from contract mating that the imported semen of FS5 mated to top 5 % PTA M cows. Bulls were proven by their 100 daughters' performance. Semen from these bulls would be collected and stored after sampling. They would mate 80% of target cow population after proven.

(2) Untested Local elite bulls for AI and NS (LB/AI/NS).

20 AI bulls and 200 NS bulls were produced from the same contract mating as PT/AI. 20 AI bulls were selected by the rank of estimated Parent Average (PA) for PTA M to sire of 80% cows by AI. 200 NS bulls were in 200 herds. Each bull mated to 30 cows in the herd by NS and would contribute to 6% of target population genetic progress.

(3) Nucleus population with Multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls (MOET/AI/NS)

20 AI bulls and 200 NS bulls were produced from the controlled Nucleus population bred by Multiple Ovulation and Embryo Transfer (MOET) techniques. AI bulls were selected by the estimated Parent Average (PA) for PTA M to sire of 80% cows by AI. 200 NS bulls from MOET were in 200 herds. Each bull mate to 30 cows in the herd by NS and would contribute to 6% of target population genetic progress.

(4) Untested bulls from imported foreign embryos for AI (untFEB)

Ten AI untested bulls were produced from imported frozen embryos but transferred in local recipients. These embryos were from planned mating of elite cows and bulls in the exporting country and selected on the estimated Parent Average (PA) for PTA M. They would mate 80 % of target cow population.

(5) AI Bulls from imported embryos tested by paternal half-sib (STFEB)

Ten AI bulls were produced from imported frozen embryos but transferred in local recipients. These embryos were from planned mating of elite cows and bulls in the exporting country. 600 doses semen of the sires of embryos would also imported at the same time so that there would be 100 paternal half-sib to the bulls. Bulls were selected by the half-sister performance in the local population.

(6) Total reliance on foreign semen (FS40 and FS20)

A total of 227,000 doses frozen semen were imported each year to mate 80% target cow population. The imported semen were selected from the top 40% and 20 % proven bulls list on PTA M with 70% REL from the exporting countries to sire target cow population respectively.

(7) Different proportion (30% and 50%) of imported semen with different genetic quality (FS40 and FS20) combined with alternative scheme

For example, /AI+FS40-30% is above alternative breeding schemes with supplement of FS40 breed 30% of the target cow population. Four combinations were study. They were /AI+FS40-30%, /AI+FS40-50%, /AI+FS20-30%, /AI+FS20-50%.

(8) Individual breeding schemes supplemented by additional imports

Two kinds of additional imports supplemented to individual breeding schemes. One is semen importation from top 20% or 40% to breed 30% or 50% of the target cow population. The second is 5% heifers imported supplement to individuals. AI/+FpgH stands for importation of foreign pregnant heifers as 5% of the replacement females supplement AI schemes. AI/+FylH stands for importation of foreign yearling heifers as 5% of the replacement females supplement AI schemes.

The model of evaluation- NPV

The economic benefits of the genetic improvement from a breeding scheme were determined by (1) The initial cost of germplasm, (2) Price of milk produced, (3) Cost of milk production and extra costs of feeds and health and fertility problems due to increased milk production, (4) Discount rates, and (5) Time horizon.

Many authors had used discounted cash flow method to assess the value of livestock improvement schemes, and to compare alternative breeding schemes (Hill.1971,Hink.1971, Petersen.1974, Cunningham and Ryan.1975, Everett.1975). In Brascamp (1973) and Fewson (1989), benefit was discounted at a higher rate, 10% vs 8%. The justification for using higher discount rate was that it allowed for risk. Mpofu et al (1993) reported using a high discount rate (10%) to account for the risk of failure of an investment program because benefit would be recouped far beyond the 25-year horizon. However, high rates (8 to 15%) used in discounted cash flow analysis of genetic improvement schemes had tended to underestimate the value of the benefit and to favor breeding schemes with short-term benefit (Bird and Mitchell.1980, Smith.1978). In this study, investments and the infrastructure of breeding schemes did not be concerned and truncating benefit at the end of the evaluation period rather than counting them in perpetuity, the risk could be ignored and the discount rates could be lower. So the discount rate used in this study was 5% for the economic efficiency evaluation. This rate was recommended for most animal breeding programs (Dekkers and Shook.1990).

Therefore, the expected benefit from a breeding scheme would be calculated by discounted Net Present Value (NPV) of accumulated benefits from the achievable genetic progress in milk at year *25*. Benefits from the achievable genetic progress in milk were net return of additional milk due to genetic improvement over feeds and health cost subtracted the breeding cost.

The Net Present Value (NPV) of the accumulated benefits for a breeding scheme was calculated as

$$NPV = \sum_{t=1}^{T}[(R_{BS(t)} - C_{BS(t)})/(1+d)^t]$$

$$= \sum_{t=1}^{T}[(B_{BS(t)})/(1+d)^t]$$

Where t: the evaluation period (year 0 to year 25), which was 26 years,
d: the discount rate 5%,
$R_{BS(t)}$: the total yearly net return of milk yield from a breeding scheme at year t,
$C_{BS(t)}$: the total costs paid by farmers for semen from bulls produced from the proposed breeding scheme at year t, and
$B_{BS(t)}$: the value of the benefit for farmers from a breeding scheme at year t

The economic efficiency of a proposed breeding scheme was determined by the difference of the discounted NPV of accumulated relative benefits at year *25* between an alternative breeding scheme ($B_{ABS(t)}$) and the current breeding scheme.

$$NPV \cdot of \cdot relative \cdot benefit \cdot to \cdot CBS$$

$$= \sum_{t=1}^{T}[(B_{ABS(t)} - B_{CBS(t)})/(1+d)^t]$$

If NPV difference of accumulated benefit at year 25 between an alternative-breeding scheme ($B_{ABS(t)}$) and current breeding scheme ($B_{CBS(t)}$) was negative, it meant the alternative-breeding scheme was not better than the current breeding scheme. Positive NPV difference meant alternative breeding scheme was economically viable. The NPV was also used to rank the proposed breeding schemes.

Calculating NPV of benefit

Table 4-1 showed the average total costs of milk production and benefit per hundred kg for Target population dairy farmers in 1997. These data were obtained from the file of Council of Agriculture. The costs were representative of typical commercial dairy farms in Target population. Milk production costs were the costs incurred by overheads which include real estates, buildings, fencing, electricity, and dairy equipment, tractor, feeds, veterinary services, vet supplies, shipping, selling charges, insurance, basic overhead expenses (e.g. living expenses of farmers) and miscellaneous costs. For the production cost of extra milk yield due to genetic improvement, only the feed costs and health-fertility costs were considered. In Table 4-1, the feed costs would be 50% of milk price per kilogram. Health-fertility costs would be 4% of milk price per kilogram. Here, the production cost for extra milk from genetic improvement would be taken as 40 % of milk price per kilogram.

A summary of values was given in Table 4-2 for calculating benefit from the proposed breeding scheme. They were based on the market price in 1997 in target population. In this study, milk price was fixed at 1997 market price which was $.61 per kg. When the supply of milk increases due to genetic improvement, the market price of milk might decrease because of an increase in the consumer surplus. The price of milk was determined by the demand for dairy products. The demand was related to consumer growth. In target population, the consumer population is still low and is growing especially in young people. The growth in supply and in demand would not lead the price milk to drop.

Table 4-1. The total costs of milk production and benefit per hundred kg for target population dairy farmers in 1997

Items	$	%
Cost		
Feeds	31.38	50.20
Vets and Medicines	2.76	4.42
Labor	5.33	8.53
Insurance	.64	1.02
Electricity	.64	1.03
Depreciation of cow	3.88	6.20
Building maintenance	.71	1.18
Tool and machine depreciation	.70	1.12
Machine maintenance	.38	.60
Miscellaneous	.09	.15
Artificial Insemination plus semen price	1.13	1.80
Total cost of 100 kg of milk yield	47.44	
Income		
Market milk price in Target population 1n 1997	.61	
Total Income of 100 kg of milk yield	61	
Benefit of 100kg milk yield	13.56	22.23

Source: Cost-benefit analysis of milk production for dairy farmers in 1997

Only benefits from milk yield were considered. With the subsiding by government, farmers would derive full benefit of genetic improvement. Cost for a breeding scheme to the farmers were the price of semen per straw domestic or imported plus the AI fee. Assume the price of semen produced from the breeding scheme established by government would be $ 7 per straw. Table 4-2 showed the costs of milk production and benefit per hundred-kg milk for target population dairy farmers.

Table 4-2. Annual breeding costs to farmers for the proposed breeding schemes

Item	$/unit	Units	Total ($X10^3)
Cost			
CBS			
FS10	30	142	4
FS50	12	170,100	2,041
Semen from local untested bulls	6	56,700	340
Breeding fee for technician	10	216,000	2,160
PT/AI			
FS5	50	226	11
Semen of bulls produced from scheme	6	227,000	1,362
Breeding fee for technician	10	216,000	2,160
LB/AI/NS			
FS5	50	850	42
Semen of bulls produced from scheme	6	227,000	1,362
Breeding fee for technician	10	216,000	2,160
MOET/AI/NS			
FS5	50	850	42
Semen of bulls produced from scheme	6	227,000	1,362
Breeding fee for technician	10	216,000	2,160
untFEB			
Semen of bulls produced from scheme	6	227,000	1,362
Breeding fee for technician	10	216,000	2,160
STFEB			
FS10	30	6,000	180
Semen of bulls produced from scheme	6	221,000	1,326
Breeding fee for technician	10	21,600	216
FS40			
FS40	15	227,000	3,405
Breeding fee for technician	10	216,000	2,160
FS20			
FS20	20	227,000	4,540
Breeding fee for technician	10	216,000	2,160
/AI+FpgH			
Imported pregnant heifers from U.S	3,300	5,000	16,500
/AI+FylH			
Imported yearling heifers from U.S	2,800	5,000	16,500
Return			
Return over additional milk due to genetic improvement per kg	.36	Genetic change	-
Imported heifer salvage when sold as beef	800	5,000	4,000

The net return of milk per kg for the extra milk yield due to genetic improvement would be 60 % of milk price ($.36/kg). So the total yearly net return ($R_{ABS(t)}$)from milk yield in the cow population at year t for a breeding scheme would be

$$R_{ABS(t)} = \$US\ .36/kg * \text{genetic progress at year t} * 65000 \text{ milking cows.}$$

The total yearly costs ($C_{ABS(t)}$) for a breeding scheme were total paid by farmers for the price of semen plus the AI fee, which would be

$$C_{ABS(t)} = (\text{Price of semen} + \text{AI fee}) * 80{,}000 * 2.7 * 1.05$$

where price of semen: the market price of semen of bulls produced from breeding or cost of imported foreign semen.
80,000: the number of cows bred by AI.
2.7: the AI services per conception.
1.05: for contingency cost allowing for AI technology failure.

For importation of foreign pregnant or yearling heifers, farmers would pay costs of imported heifers. It was a kind of investment and had salvage values when the heifers were sold as beef. These salvage values would be included in the economic efficiency as benefit.

RESULTS AND DISCUSSIONS

Table 4-3 gave the genetic progress in milk yield, discounted cost, income, benefit, and NPV (Net Present Value) of benefit for each breeding scheme supplemented by importing foreign pregnant heifers or yearling heifers,. As shown was NPV of relative benefit from breeding scheme compared with that of CBS at year *25* at the discount rate 5%. The genetic progress were estimated when the initial genetic difference and genetic correlation between the US and Target population dairy population were 623kg and .7, respectively. Schemes with positive NPV of relative benefit were economically viable. It meant the proposed scheme could be used to replace CBS. The ranking of the proposed breeding schemes for NPV of relative benefit differed greatly from the ranking for genetic progress in milk yield because of large differences in costs among the schemes, as detailed in Appendix B Table 1 to 6.

Among these seven proposed breeding schemes, only four of the proposed breeding schemes which were STFEB, untFEB, MOET/AI/NS, LB/AI/NS had large positive NPV of relative benefit over 25 years and were economically viable with realistic genetic progress. FS40 would be economically viable at year 25 but NPV of relative benefit was negative before year *20*.

PT/AI and FS20 were negative NPV of relative benefit. PT/AI was negative NPV of relative benefit at year *25* but was positive NPV before year *20*. With discounting, more benefit realized in earlier years for the PT/AI. NPV of relative benefit for PT/AT was positive in earlier years but decreasing gradually over years and was eventually \$US -$1.06X10^6$ at year *25* because of lower genetic progress than that of CBS. For the importation of foreign semen schemes (FS20 and FS40), FS40 would be economically viable at year *25* but NPV of relative benefit was negative before year *20*. FS20 was negative NPV of relative benefit over all 25 years but was gradually close to zero with increasing over time. There were cumulative high costs involved in running FS20 and FS40 schemes at current commercial cost. The FS20 and FS40 schemes ranked the fourth and the fifth using genetic progress as a criterion. Yet these two schemes ranking were the last second and last third. The result was in agreement with study on economic benefits on farm level for semen importation for Colombia, Mexico and Venezuela by Holmann et al. (1990). Average economic benefits were negative for the three countries.

Table 4-3. Economic evaluation for individual scheme at year *25*.

Scheme[1]	Genetic progress in milk yield	Cost	Return	Benefit	Accumulated NPV at year *25*: Benefit	Deviation from CBS	% of CBS
	---- kg ----	($X10^6)					------%------
CBS							
	1588	1.37	26.01	24.63	940.72	0	100
PT/AI	1338	1.07	24.66	23.59	939.67	-1.06	99
+FpgH	1703.	5.88	28.10	22.22	815.29	-125.43	87
+FylH	1658	5.14	27.86	22.71	847.12	-93.61	90
LB/AI/NS	1667	1.08	26.43	25.35	967.50	26.77	103
+FpgH	2030	5.89	29.86	23.97	844.30	-96.43	90
+FylH	1989	5.21	29.64	24.42	873.63	-67.10	93
MOET/AI/NS	1948	1.07	27.94	26.87	986.57	45.85	105
+FpgH	2286	5.88	31.23	25.35	862.10	-78.63	92
+FylH	2251	5.21	31.05	25.84	892.03	-48.69	95
untFEB	2053	1.07	28.50	27.43	1001.03	60.31	106
+FpgH	2348.	5.88	31.57	25.69	871.48	-69.24	93
+FylH	2321	5.21	31.42	26.21	903.57	-37.16	96
STFEB	2246	1.06	29.54	28.48	1007.24	66.52	107
+FpgH	2523	5.87	32.50	26.64	877.76	-62.97	93
+FylH	2500	5.20	32.38	27.19	908.42	-32.31	97
FS40	1771	1.67	26.99	25.31	941.40	0.68	101
+FpgH	2095	6.44	30.20	23.76	815.93	-124.80	87
+FylH	2061	5.81	30.02	24.21	843.46	-97.26	90
FS20	1856	2.01	27.44	25.44	935.80	-4.93	99
+FpgH	2171	6.76	30.61	23.86	810.37	-130.35	86
+FylH	2139	6.14	30.44	24.30	837.12	-103.61	89

[1]CBS= Current Breeding Scheme, PT/AI= Progeny Tested bulls for AI, untLB/AI/NS= Untested Local elite bulls for AI and NS, MOET/AI/NS= Nucleus population with multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls, UntFEB= Untested bulls from imported foreign embryos for AI, STFEB= AI Bulls from imported embryos tested by paternal half-sibs , FS40= The imported semen selected from the top 40% proven bulls in U.S., FS20= The imported semen selected from the top 20% proven bulls in U.S., +FpgH= Importation of foreign pregnant heifers as the replacement females supplement to AI scheme. +FylH= Importation of foreign yearling heifers as the replacement females supplement to AI scheme.

For LB/AI/NS, NPV of relative benefit was with low increasing rate over years and was positive at year *25*.

MOET/AI/NS was better than CBS, PT/Al and LB/AI/NS by 5%, 6% and 2%, respectively. In Dekkers and Shook (1990a) work, the juvenile MOET schemes were better than progeny testing. Fewson (1989) found that profits were almost the same for progeny testing and a MOET scheme, those of the progeny testing scheme being 3% higher. In this study, the nucleus population of MOET/AI/NS scheme was an open one. Bull sires were selected from foreign. The nucleus population was expected to be a lot better genetically than the target since it were better kept open to migration from foreign populations.

The scheme ranking first through third were STFEB, FEB and MOET/AI/NS and were the same as that of genetic progress. In this study, the genetic advantage of STFEB and FEB over MOET/AI/NS was the use of foreign bull dams. The genetic means at year *25* for STFEB was higher than that for MOET/AI/NS by a factor of 15% while the relative NPV for STFEB was higher than that of MOET/AI/NS by a factor of 2%. The genetic means at year *25* was higher for STFEB than for FEB by a factor of 4% while the relative NPV for STFEB was higher than that of FEB by a factor of 1%. The genetic means at year *25* was higher for FEB than for MOET/AI/NS by a factor of 5.3% while the relative NPV for FEB was higher than that of MOET/AI/NS by a factor of 1%. Use of imported embryos to produce AI bulls was ranked as the best (STFEB) and the second best (FEB) of all of the proposed breeding schemes, surpassing CBS, respectively, by 7% and 6%.

Total reliance on foreign semen (FS40 and FS20) to mate target population was not economic viable scheme. But different proportion (30% and 50%) of imported semen with different genetic quality (FS40 and FS20) combined with alternative scheme in

Table 4-4 were showed economic viable. Yet, the difference of NPV of benefit from that of CBS was less than that of individual breeding schemes except PT/AI. PT/AI combined with importing foreign semen at different proportion become economic viable with the most when combined with FS40-30%.

None of those schemes supplemented by importing foreign pregnant or yearling heifers was economically viable alternatives. They were not viable even though each heifers imported had a salvage value of $800 in addition to their contribution to genetic progress to the population.

Genetic correlation between two populations did not affect significantly the ranking of schemes based on economic efficiency evaluation in Table 4-5 but had an effect on the absolute values of the NPV of relative benefit because r_g affected the magnitude of genetic progress. PT/AI scheme became economic viable when r_g was 0.9. This result was agreed to that of Mpofu et al (1993). They reported when no interaction in performance occurs between countries, the importation strategies have higher NPV, but the ranking of proposed breeding schemes was little changed. When the interaction increased (r_g became less), the local testing strategies improved relatively in their NPV.

Economic efficiency analysis help to identify economical viable schemes and the optimum breeding scheme based on whether it would contribute significantly to the development of the economy or benefit to farmers. The study showed that STFEB was an optimum-breeding scheme in terms of genetic improvement and economic efficiency for Target population dairy cattle population. The cost of STFEB was list in Table 4-6 for bulls selection program. If this scheme was adopted by the government agencies, a bull station needed to be established and experienced technicians for frozen embryos transfer

Table 4-4. Economic evaluation for individual schemes with supplement of FS40 or FS20 to breed 30% or 50% cow population at year *25*

Breeding Scheme [1]	Genetic progress in milk yield	Cost	Income	Benefit	NPV deviation from CBS
	---- kg ----	($X10^6)			
CBS	1588.68	1.37	26.01	24.63	0
PT/AI	1338.78	1.07	24.66	23.59	-1.06
+FS40-30%	1521.38	1.21	25.64	24.42	4.06
+FS40-50%	1580.76	1.31	25.96	24.64	3.61
+FS20-30%	1546.10	1.29	25.77	24.47	2.87
+FS20-50%	1620.51	1.45	26.17	24.72	1.57
LB/AI/NS	1667.27	1.08	26.43	25.35	26.77
+FS40-30%	1729.12	1.22	26.76	25.53	23.02
+FS40-50%	1766.33	1.32	26.96	25.64	20.32
+FS20-30%	1757.12	1.30	26.91	25.60	22.16
+FS20-50%	1810.63	1.45	27.20	25.74	18.78
MOET/AI/NS	1948.97	1.07	27.94	26.87	45.85
+FS40-30%	1932.94	1.21	27.85	26.63	37.01
+FS40-50%	1922.20	1.31	27.79	26.48	31.13
+FS20-30%	1954.65	1.29	27.97	26.67	35.84
+FS20-50%	1958.45	1.44	27.99	26.54	29.18
untFEB	2053.13	1.07	28.50	27.43	60.31
+FS40-30%	1985.32	1.21	28.13	26.82	45.99
+FS40-50%	1940.25	1.31	27.89	26.58	36.45
+FS20-30%	2005.35	1.29	28.24	26.95	44.65
+FS20-50%	1974.24	1.44	28.07	26.63	34.21
STFEB	2246.05	1.06	29.54	28.48	66.52
+FS40-30%	2052.32	1.19	28.49	27.30	45.44
+FS40-50%	1993.65	1.28	28.18	26.89	36.61
+FS20-30%	2073.43	1.27	28.61	27.34	44.40
+FS20-50%	2027.63	1.40	28.36	26.95	34.88

[1]CBS= Current Breeding Scheme, PT/AI= Progeny Tested bulls for AI, untLB/AI/NS= Untested Local elite bulls for AI and NS, MOET/AI/NS= Nucleus population with multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls, UntFEB= Untested bulls from imported foreign embryos for AI, STFEB= AI Bulls from imported embryos tested by paternal half-sibs , FS40= The imported semen selected from the top 40% proven bulls in U.S., FS20= The imported semen selected from the top 20% proven bulls in U.S., +FpgH= Importation of foreign pregnant heifers as the replacement females supplement to AI scheme.+FylH= Importation of foreign yearling heifers as the replacement females supplement to AI scheme.

Table 4-5. The effect of genotype by environment interaction on NPV of relative benefit to that of CBS from the proposed breeding schemes at year *25*.

Breeding scheme[1]	NPV of relative benefit to CBS from scheme		
	r_g =.5	r_g =.7	r_g =.9
	($\$X10^6$)		
CBS	0	0	0
PT/AI	-2.13	-1.06	0.02
UntLB/AI/NS	24.85	26.77	28.72
MOET/ AI/NS	42.01	45.85	49.32
untFEB/AI	59.14	60.31	61.47
STFEB/AI	57.21	58.70	60.02
FS40	-0.63	0.68	2.03
FS20	-9.53	-4.93	-0.37

[1]CBS= Current Breeding Scheme, PT/AI= Progeny Tested bulls for AI, untLB/AI/NS= Untested Local elite bulls for AI and NS, MOET/AI/NS= Nucleus population with multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls, UntFEB= Untested bulls from imported foreign embryos for AI, STFEB= AI Bulls from imported embryos tested by paternal half-sibs , FS40= The imported semen selected from the top 40% proven bulls in U.S., FS20= The imported semen selected from the top 20% proven bulls in U.S.,

Table 4-6. Yearly costs for bull station to adopt STFEB scheme

Items	Calculation	$ ($X10^3$)
Bull station investment	312,500	312.50
Items replacement per year	312,500*0.05	15.62
Importing frozen embryos	1,000*56(STFEB)	56.00
Hormone for synchronizing recipients[1]	40*56embryos*4	8.96
Bull maintenance costs	2,800*10 bulls	28.00
Young bull maintenance costs	2,100*14 bulls	29.40
Yearling bulls maintenance	1,700*10 bulls	17.00
Semen collection, storage, and delivery	2*227,000 straws	454.00
Total		921.00
Overheads for bull station per year		609.00
Income for semen sale	7*227,000 straws	1,589.00

[1] Four heifers were prepared for one embryo transferring.

were employed by the government. These two factors related to the success of this scheme. The cost in Table 4-6 did not include the salary of these technicians. The bull station got income from sale of semen, which were $1,589,000 a year. The amount could cover the overheads of bull station.

Mpofu et al (1993) proposed breeding strategies for genetic improvement of dairy cattle in Zimbabwe. The strategy that ranked best economically was the continuous importation of elite embryos to generate young untested bulls, which was like as untFEB in this study.

IMPLICATIONS AND CONCLUSIONS

This study proposed 8 alternative breeding strategies and several combinations of them, all were practical for application in the target population for genetic improvement for milk yield. Among these proposed breeding schemes, STFEB was a practical and the optimum breeding scheme in terms of both the rate of genetic progress and economic efficiency. In this scheme, imported elite embryos would produce bulls as sire of cows (SC) and imported 6000 straws of semen from sires of embryos, which was FS10, as SC to mate cows in the target population to produce paternal half-sibs to test the bulls produced from embryos. Both bulls from embryos and bulls of sires of embryos contributed genetic progress to the population.

The second optimum scheme was untFEB. This scheme did not import FS10 to mate cows and the number of embryos was less and the cost of this scheme was cheaper than STFEB. Yet, more genetic gain in milk yield could cover the extra cost and appeared to be the optimum breeding scheme.

MOET/AI/NS scheme was a local selection scheme and was the third optimum scheme. Schemes utilizing local resources such as MOET/AI/NS and LB/AI/NS would also result in higher genetic progress in milk yield at 25 years than that resulted from

CBS and be also economic viable. These two schemes were special tail-made alternative breeding schemes for target dairy situation. NS bulls produced from MOET in nucleus population or contract matings with known genetic merit would contribute genetic progress to the population and improve reproductive efficiency too. For the nucleus population, benefits would also come from sale of these NS bulls that were not included in the evaluation.

Total reliance on FS20 was not economically viable due to expensive import cost though it result in higher genetic gain. FS20 ranked forth based on genetic improvement, but ranked the last based on economic efficiency. FS40 was economically viable. It implicated that the imported semen didn't need to be from the best bulls in the exporting country. The most important was that the bulls should be of higher genetic merit in exporting country than top 40% progeny tested proven bulls in the importing country.

PT/AI has been the backbone scheme of dairy cattle improvement in most developed countries. In this study, PT/AI was the only scheme which genetic gain and NPV of relative benefit was lower than those of CBS. The rank of PT/AI was the last based on genetic improvement, but still ranked near the bottom based on economic efficiency.

Importation of FS20 or FS40 to breed 30% or 50% cows combined with LB/AI/NS would result in higher genetic improvement and less NPV of benefit. But MOET/AI/NS, untFEB, and STFEB with supplement of importation of FS20 or FS40 to breed 30% or 50% cows, the genetic improvement were lower and NPV of benefits were less than those of individual schemes without supplement.

Individual breeding schemes with supplement of importation of 5% pregnant heifers or 5% yearling heifers resulted in the magnitude of the genetic improvement higher than those without supplement. But they all were not economic viable.

The results of this study indicated that foreign elite bulls and foreign elite dams of bulls must be more effectively used because of the great initial genetic difference between the target and the U.S. dairy cattle populations. Even the genetic by environment interaction existed, effective use of foreign elite bulls and foreign elite dams of bulls still could make maximal genetic progress. Some of the other alternatives within each of schemes and combined with other schemes might make them more efficient. Imports of high quality foreign semen from elite bulls to mate only higher performance local cows with some proportion might be economic viable breeding practice. We didn't use the females from embryos as bull-dams. The genetic merit of these females from embryos should be as elite as the bulls from the embryos. They should be used as bull-dams in PT/AI, LB/AI/NS and even MOET/AI/NS scheme, especially in the earlier years.

CONCLUSIONS

Sale of milk is the major source of income for most dairy producers. Milk yield, therefore, should receive heavy emphasis in selection programs. The dairy population around the world is decreasing in size. This fact means genetic improvement in milk yield is continuous increasing through breeding and the dairy producers must become as efficient and as profit-minded as possible.

Milk yield was closely related to economic merit. The genetic response in milk yield would steadily be increasing keeping on selection with various currently available selection criteria from USDA and Holstein Association USA. When milk was paid for its volume with a fat differential or with both fat and protein differential, selection on PTA M could get largest response in milk yield with small difference on MF$, MFP$, NM$. These milk yield selection criteria would also increase SCS in milk while much less from selection on NM$. Linear type traits such as rear leg of side view, rump angle, fore udder attachment, udder depth and teat placement would be resulted in undesirable responses. These undesirable responses probably be the cause the health and fertility stress problems. If the severity of these undesirable responses increased, the value of increased milk yields would be offset by the additional cost for these undesirable responses.

When farmers set up breeding goal to breed a more profitable herd without concern about cow shape, they might use yield or yield merit or NM$ as selection criterion. They select AI sires with high value of these selection criteria and then scrutinized heavily for PTA SCS and for linear type traits such as fore udder attachment and udder depth. If farmers wanted to change cow conformation to meet their personal standards, selection on TPI or additional selection pressure on linear type traits after screening on yield selection criteria would be a better sire selection practice.

There is a variety of breeding schemes designed for dairy industry in the world. This study cited 8 alternative breeding strategies and schemes with additional supplement of imported germplasm which were all practical under target population conditions. Because all breeding schemes involved importation of foreign germplasm, the factors, which influenced genetic gains such as inbreeding depression and genetic drift, are ignored.

Among these proposed breeding schemes, STFEB scheme could result in highest genetic gain in milk yield at year 25. In this scheme, imported elite embryos produced bulls as SC and imported 6000 straws of semen from sires of embryos, which was FS10, were also as SC to mate cows in target to produce paternal half-sibs to test the bulls produced from embryos. Both bulls from embryos and bulls of sires of embryos contributed genetic progress to the population. A large amount of importation costs imposed on this scheme. Yet, economic efficiency evaluation showed that more genetic gain in milk yield could cover the extra cost and obtained more benefits at year *25*. STFEB appeared to be the best optimum practical breeding scheme.

The second optimum scheme was untFEB. This scheme did not import FS10 to mate cows and the number of embryos was less and the cost of this scheme was cheaper than STFEB. The genetic progress at 25 years of total reliance on foreign semen was higher than that from CBS. FS40 and FS20 could make higher and faster genetic gains because they were from dairy populations with a genetic mean higher than that of target population. The genetic progress adopting FS20 or FS40 schemes showed that the genes flow from the foreign population to the importing population was faster in SC path than in SB path. Economic efficiency evaluation showed that FS20 were not economic viable due to expensive import cost though it result in higher genetic gain. FS40 was economic viable. It implicated that the imported semen didn't need to be from the best bulls in the exporting country.

Amongst the schemes utilizing local resources, MOET/AI/NS was better than CBS, PT/Al and LB/AI/NS respectively. Poor reproductive efficiency of dairy cows was an obstacle to genetic improvement because of long generation interval. MOET/AI/NS and LB/AI/NS produced AI and NS bulls. These two schemes were special tailor-made alternative breeding schemes for Taiwan dairy situation. NS bulls produced from MOET or contract matings with known genetic merit and would contribute genetic progress to the population and improve reproductive efficiency. These NS bulls, however, would only stay as NS bulls for two years in herd, each herd only with one NS bull. Each bull would only mate 30 cows a year in a herd. Genetic contribution from them to the population was only 6%. To produce more NS bulls with known genetic merit and AI bulls with high genetic merit, MOET and IVFP could make it and would be very important technologies applied to breeding scheme in Taiwan in future study.

PT/AI was the only scheme which genetic gain and NPV of relative benefit was lower than those of CBS. Lower selection intensity and long generation interval limited the genetic gain. It is unlikely that all individual breeding schemes were adopted alone. PT/AI combined with all other proposed schemes such MOET/AI/NS, untFEB, and STFEB, and even proportion of FS20 or FS40 should be resulted in higher genetic improvement and more economical efficiency.

The results of this study implied that target dairy population should be more effective use of foreign elite bulls and foreign elite dams of bulls as SB or DB because of the high initial genetic difference between the target and US dairy cattle population. Even the genetic by environment interaction existed, effective use of foreign elite bulls and foreign elite dams of bulls still could make maximal genetic progress. Some of other alternation within each of schemes and combined with other schemes might make them more efficient. Imports of high quality foreign semen from elite bulls to mate only higher performance local cows with some proportion might be economic viable breeding practice. The use of females from embryos as DB in PT/AI, LB/AI/NS and even MOET/AI/NS scheme especially in the earlier years should be more effective.

When genotype by environment interactions exist, the best genotype in one environment was not the best in another. Using Taiwan dairy cattle milk yield data files to evaluate the genetic correlation between Taiwan and US population was also a important study in the recent future.

In this study, only milk yield was of interest. Because of specific resources, management system and environment in Taiwan, other traits of dairy cows such as type traits, stress resistant traits, fertility, calving ease, mastitis resistance, and even general health should be monitored when improvement focus on milk yield. To develop a total merit index with economic weights is important for the future studies. Future study should move towards improvement in multi-trait breeding goal but not reduce milk yield much.

APPENDIX A

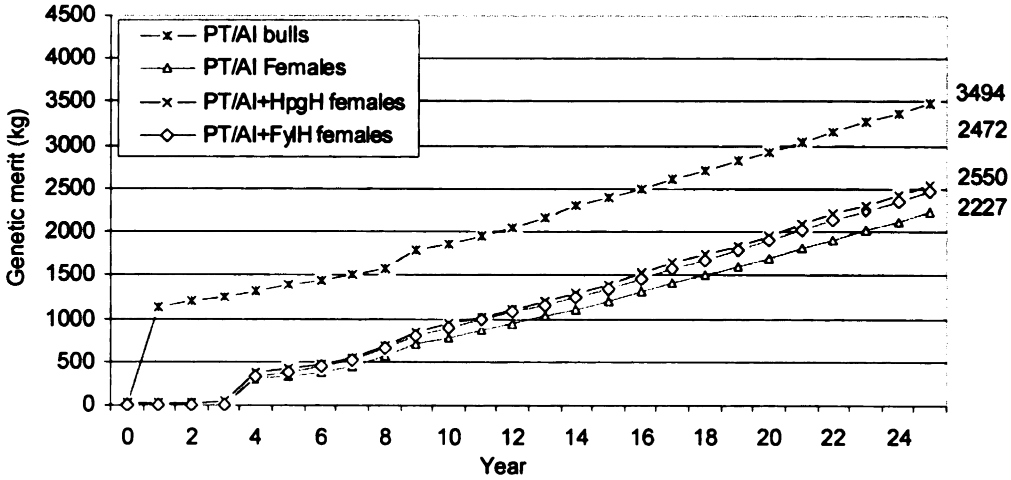
APPENDIX A

Table 1. Average breeding value by birth year for milk yield of the U.S. Holstein.

Year	Cows	BV	Sire BV
57	31273	-5069	-4918
:	:	:	:
60	137257	-5001	-4827
:	:	:	:
65	188330	-4625	-4381
:	:	:	:
70	247104	-4101	-3682
:	:	:	:
75	315750	-3300	-2675
:	:	:	:
80	540206	-2286	-1425
:	:	:	:
85	615421	-1208	-374
86	638114	-986	-137
87	663625	-767	74
88	679817	-516	339
89	692542	-237	651
90	702666	0	880
91	703594	279	1197
92	680665	571	1515
93	651727	838	1791
94	656233	1100	2061
95	635800	1321	2270

AIPL - USDA report (1998,FEB)

APPENDIX A



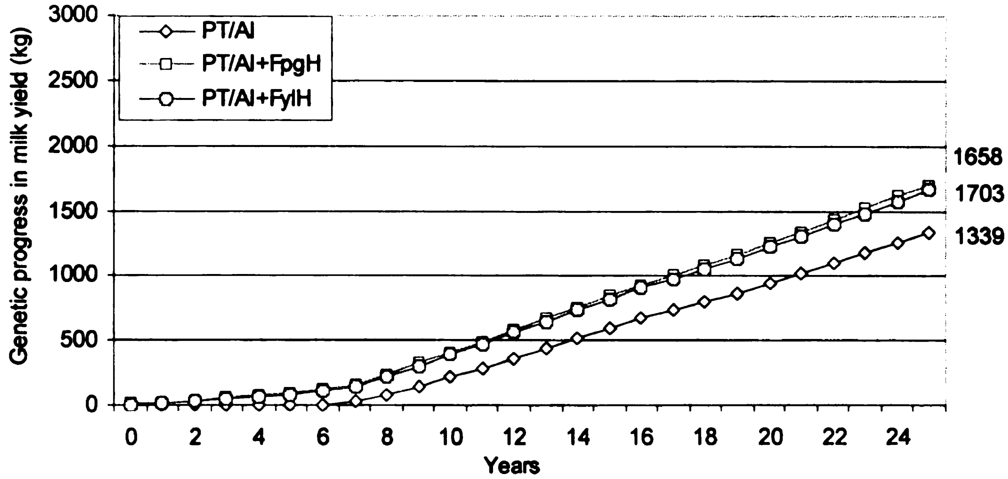
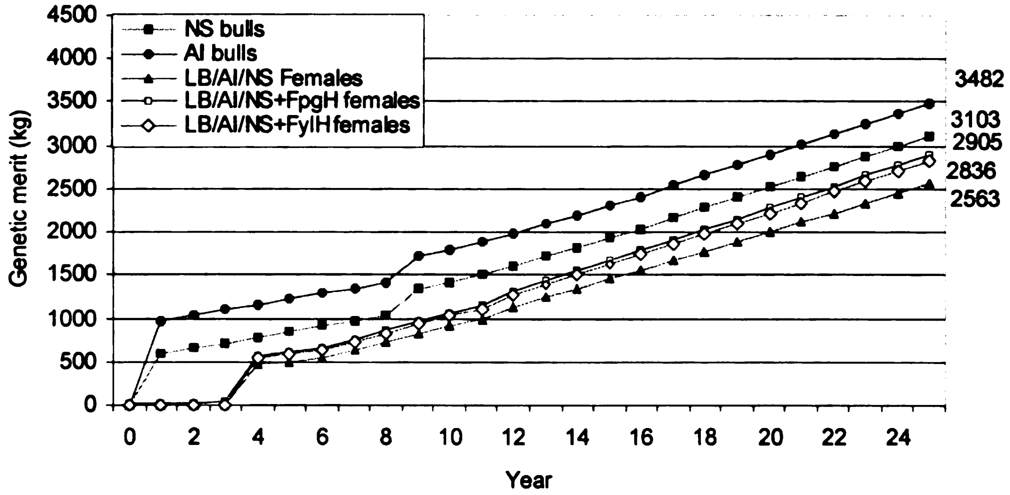


Figure 1. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for PT/AI [1] and supplement by FpgH[2] and FylH[3]

[1] PT/AI= progeny tested bulls for AI
[2] FpgH= scheme with supplement of imported pregnant heifers
[3] FylH= scheme with supplement of imported pregnant heifers.



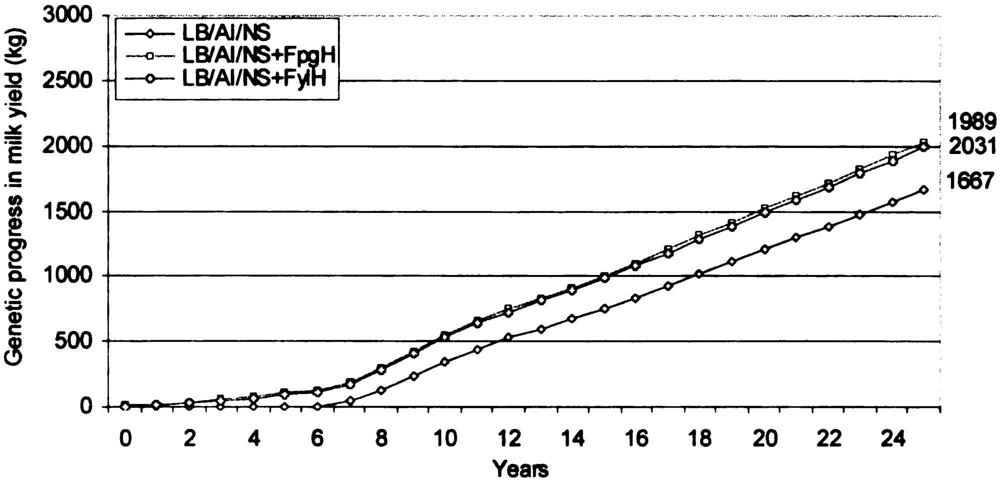


Figure 2. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for untLB/AI/NS [1] and supplement by FpgH[2] and FylH[3]

[1] untLB/AI/NS = Untested Local elite bulls for AI and NS
[2] FpgH = scheme with supplement of imported pregnant heifers
[3] FylH = scheme with supplement of imported pregnant heifers.

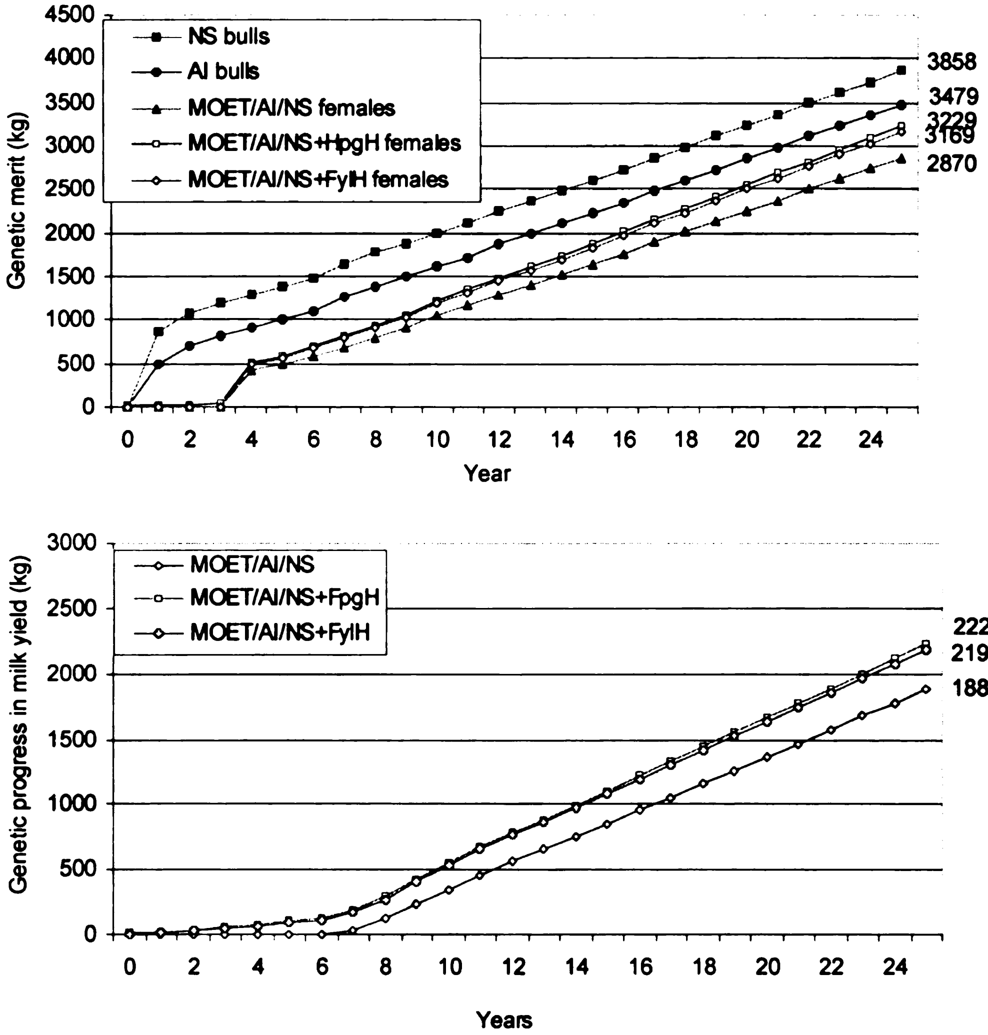


Figure 3. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for MOET/AI/NS[1] and supplement by FpgH[2] and FylH[3]

[1] MOET/AI/NS= Nucleus population with Multiple Ovulation and Embryo Transfer to produce AI bulls and NS bulls,

[2] FpgH= scheme with supplement of imported pregnant heifers

[3] FylH= scheme with supplement of imported pregnant heifers.

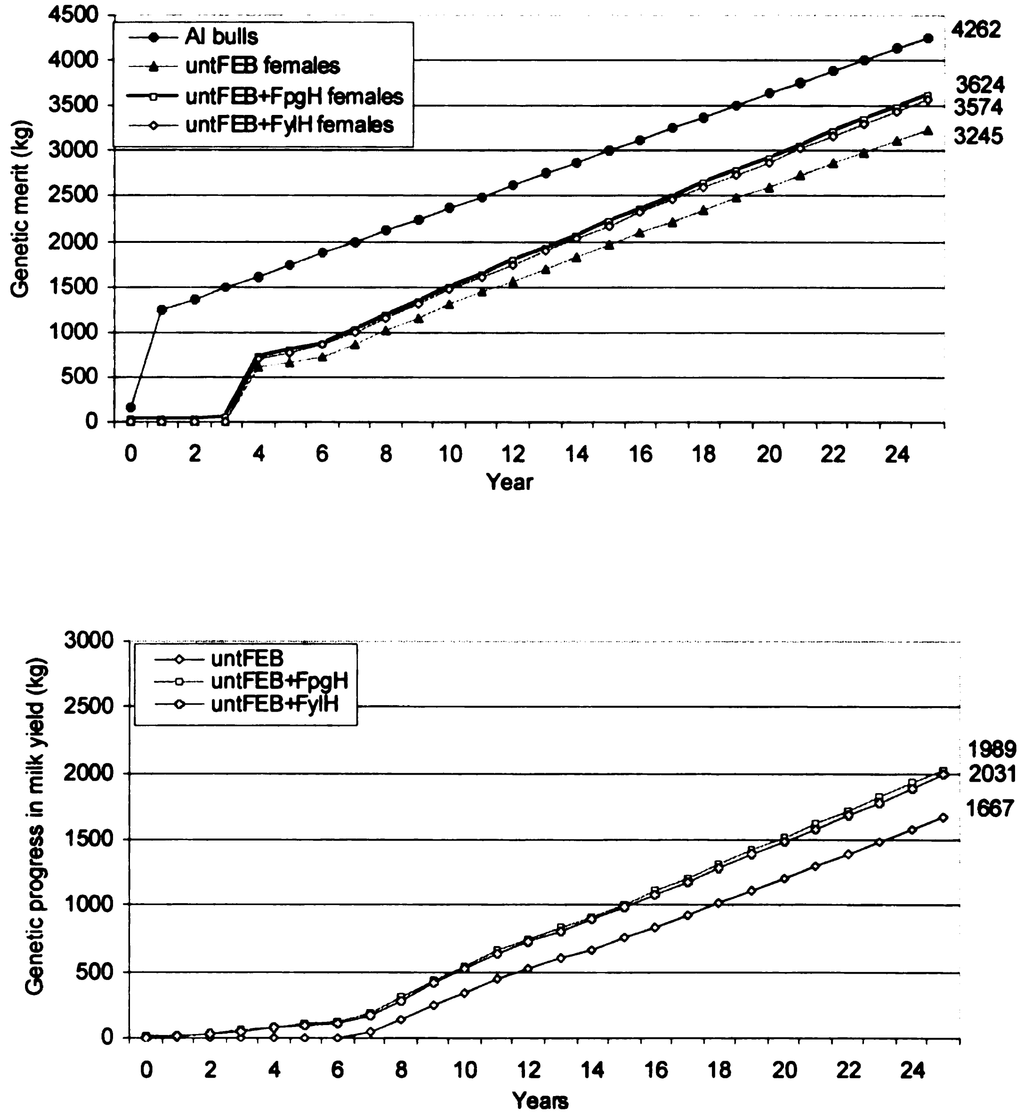


Figure 4. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for untFEB/AI [1] and supplement by FpgH[2] and FylH[3]

[1] untFEB/AI= Untested bulls from imported foreign embryos for AI
[2] FpgH= scheme with supplement of imported pregnant heifers
[3] FylH= scheme with supplement of imported pregnant heifers.

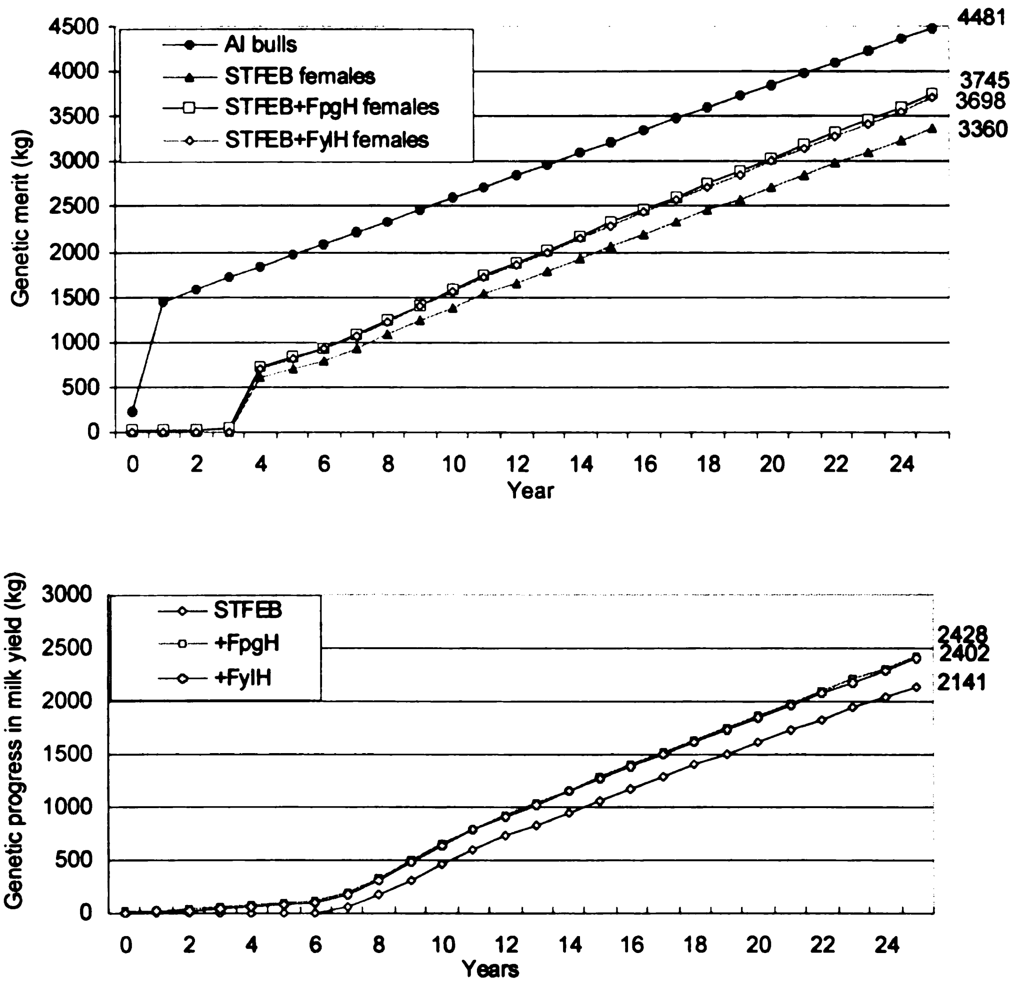
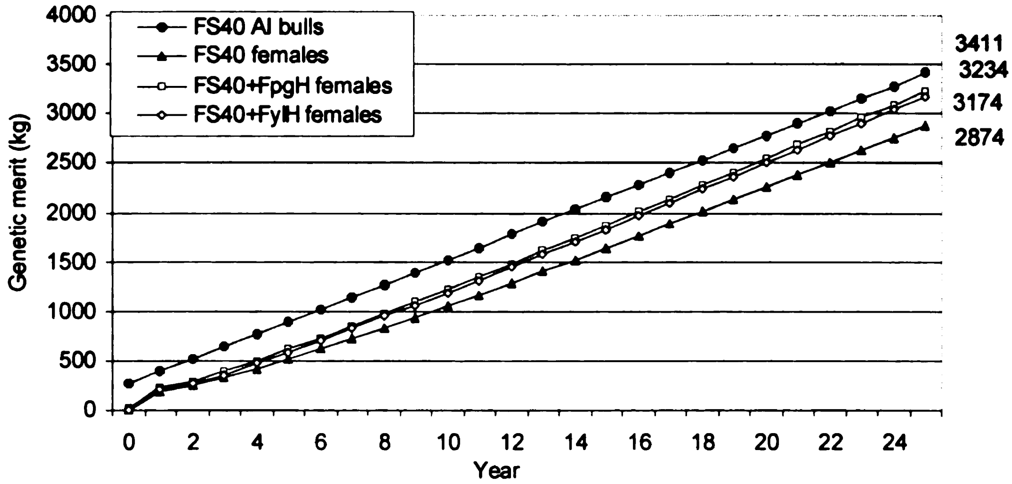


Figure 5. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for STFEB/AI [1] and supplement by FpgH[2] and FylH[3]

[1] STFEB/AI= AI Bulls from imported embryos tested by paternal half-sibs
[2] FpgH= scheme with supplement of imported pregnant heifers
[3] FylH= scheme with supplement of imported pregnant heifers.



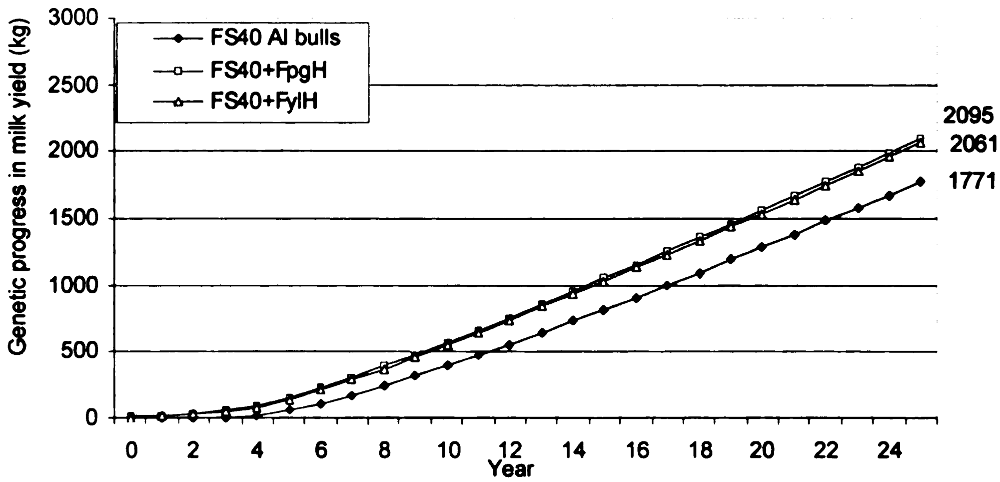
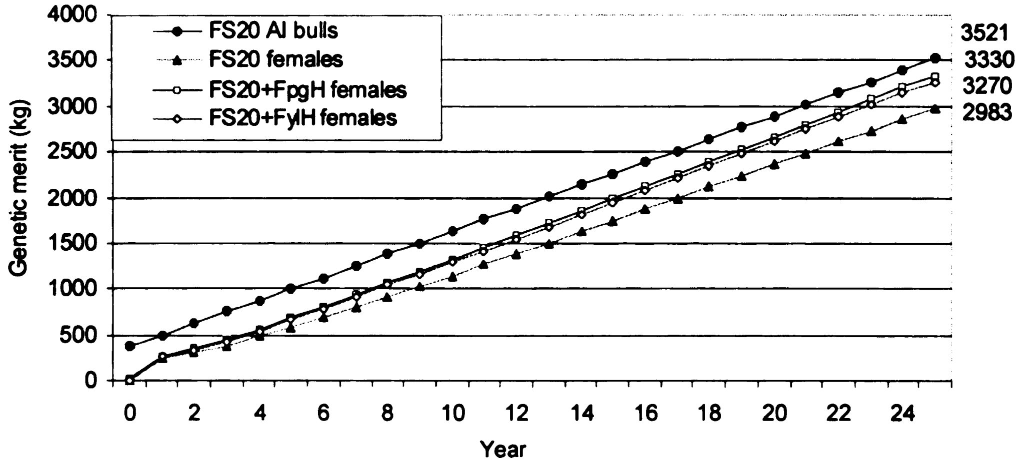


Figure 6. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for FS40 [1] and supplement by FpgH[2] and FylH[3]

[1] FS40= The imported semen selected from the top 40% proven bulls in U.S.
[2] FpgH= scheme with supplement of imported pregnant heifers
[3] FylH= scheme with supplement of imported pregnant heifers.



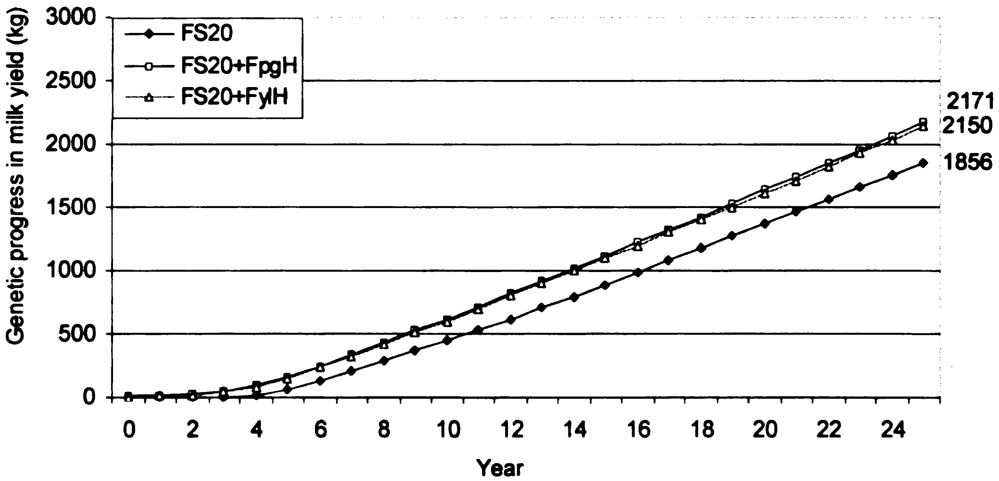


Figure 7. Estimated genetic trend of breeding stock populations and genetic progress of the target cow population for FS20 [1] and supplement by FpgH[2] and FylH[3]

[1] FS20= The imported semen selected from the top 40% proven bulls in U.S.
[2] FpgH= scheme with supplement of imported pregnant heifers
[3] FylH= scheme with supplement of imported pregnant heifers.

APPENDIX B

APPENDIX B

Table 1. Economic efficiency evaluation for individual schemes using local bull-dams over 25 years

Year	Genetic progress in milk	Cost (2)	Income (2)	Benefit (1)(2)	NPV of benefit (3)	NPV difference of benefit from CBS (3)
	---kg---	-----$X10^6-----				
CBS						
0	0.00	3.74	59.15	55.41	55.41	0
5	37.33	3.64	46.88	43.23	293.74	0
10	319.00	2.85	39.88	37.02	490.07	0
15	701.76	2.24	34.60	32.36	660.90	0
20	1131.97	1.75	30.06	28.31	810.35	0
25	1588.68	1.37	26.01	24.63	940.72	0
PT/AI						
0	0.00	0.01	59.15	59.14	59.14	3.74
5	0.00	2.85	46.35	43.50	306.24	12.50
10	213.99	2.23	38.70	36.47	499.95	9.88
15	594.49	1.75	33.66	31.91	668.41	7.52
20	945.10	1.37	28.78	27.41	814.29	3.94
25	1338.78	1.07	24.66	23.59	939.67	-1.06
LB/AI/NS						
0	0.00	0.04	59.15	59.11	59.11	3.70
5	0.00	2.87	46.35	43.48	306.08	12.34
10	343.37	2.25	40.15	37.90	503.14	13.07
15	751.88	1.76	35.03	33.28	679.24	18.34
20	1207.15	1.38	30.57	29.19	833.24	22.89
25	1667.27	1.08	26.43	25.35	967.50	26.77
MOET/AI/NS						
0	0.00	0.00	59.15	59.15	59.15	3.74
5	0.00	2.84	46.35	43.50	306.28	12.53
10	350.28	2.23	40.23	38.00	503.25	13.17
15	893.76	1.75	36.28	34.53	683.38	22.49
20	1424.68	1.37	32.07	30.70	844.62	34.27
25	1948.97	1.07	27.94	26.87	986.57	45.85

(1) Income – Cost

(2) Discounted value

(3) Discounted accumulated value

Table 2. Economic efficiency evaluation for individual schemes using imported germplasms over 25 years

Year	Genetic progress in milk	Cost (2)	Income (2)	Benefit (1)(2)	NPV of benefit (3)	NPV difference of benefit from CBS (3)
	---kg---	---$X10^6---				
untFEB						
0	0.00	0.00	59.15	59.15	59.15	3.74
5	0.00	2.84	46.35	43.50	306.28	12.53
10	429.56	2.23	41.11	38.88	505.56	15.48
15	1001.69	1.75	37.22	35.48	690.45	29.55
20	1535.44	1.37	32.83	31.46	855.89	45.53
25	2053.13	1.07	28.50	27.43	1001.03	60.31
STFEB						
0	0.00	3.60	59.15	55.55	55.55	0.15
5	2.99	2.82	46.39	43.57	296.13	2.38
10	476.71	2.21	41.64	39.43	496.83	6.76
15	1112.45	1.73	38.19	36.46	686.02	25.13
20	1691.37	1.36	33.89	32.54	856.76	46.41
25	2246.05	1.06	29.54	28.48	1007.24	66.52
FS40						
0	0.00	5.67	59.15	53.48	53.48	-1.93
5	54.55	4.44	47.12	42.68	286.03	-7.71
10	391.89	3.48	40.69	37.21	482.32	-7.75
15	816.88	2.73	35.60	32.88	655.10	-5.79
20	1284.24	2.14	31.10	28.97	807.63	-2.72
25	1771.38	1.67	26.99	25.31	941.40	0.68
FS20						
0	0.00	6.80	59.15	52.35	52.35	-3.06
5	68.69	5.33	47.33	41.99	280.25	-13.49
10	447.06	4.18	41.31	37.13	475.25	-14.82
15	890.05	3.27	36.24	32.97	648.25	-12.64
19	1268.84	2.69	32.55	29.85	772.30	-9.75
20	1365.58	2.56	31.66	29.10	801.39	-8.96
25	1856.50	2.01	27.44	25.44	935.80	-4.93

(1) Income – Cost

(2) Discounted value

(3) Discounted accumulated value

Table 3. Economic efficiency evaluation for individual schemes using local bull-dams supplemented by importing pregnant heifers over 25 years

Year	Genetic progress in milk	Cost (2)	Income (2)	Benefit (1)(2)	NPV of benefit (3)	NPV difference of benefit from CBS (3)
	---kg---	----------------------	----------------------	$X10^6	----------------------	----------------------
PTAI+FpgH						
0	20.21	16.51	64.52	48.01	48.01	-7.40
5	98.32	15.60	51.67	36.07	250.24	-43.50
10	407.98	12.22	43.94	31.72	415.37	-74.71
15	848.85	9.58	38.29	28.71	564.97	-95.92
20	1254.10	7.50	32.78	25.28	698.17	-112.18
25	1703.00	5.88	28.10	22.22	815.29	-125.43
LBAI/AI/NS+ FpgH						
0	20.21	16.54	64.52	47.98	47.98	-7.43
5	104.46	15.62	51.75	36.14	250.35	-43.39
10	547.32	12.24	45.50	33.26	419.44	-70.64
15	1008.03	9.59	39.68	30.09	576.80	-84.09
20	1518.35	7.51	34.59	27.08	718.28	-92.07
25	2030.98	5.89	29.86	23.97	844.30	-96.43
MOET/AI/NS+ FpgH						
0	20.21	16.50	64.52	48.02	48.02	-7.39
5	104.46	15.59	51.75	36.16	250.55	-43.20
10	555.67	12.22	45.59	33.37	419.57	-70.51
15	1143.48	9.57	40.87	31.29	580.91	-79.99
20	1717.63	7.50	35.96	28.46	729.08	-81.27
25	2286.12	5.88	31.23	25.35	862.10	-78.63

(1) Income – Cost

(2) Discounted value

(3) Discounted accumulated value

Table 4. Economic efficiency evaluation for individual schemes using imported germplasms supplemented by importing pregnant heifers over 25 years

Year	Genetic progress in milk	Cost [2]	Income [2]	Benefit [1][2]	NPV of benefit [3]	NPV difference of benefit from CBS [3]
	---kg---	----------------------	----------------------	$\$X10^6$	----------------------	----------------------
untFEB+ FpgH						
0	20.21	16.50	64.15	47.65	47.65	-7.76
5	98.32	15.59	51.67	36.07	249.65	-44.09
10	620.34	12.22	46.31	34.10	420.37	-69.70
15	1223.56	9.57	41.57	32.00	585.32	-75.57
20	1792.43	7.50	36.47	28.97	736.44	-73.91
25	2348.47	5.88	31.57	25.69	871.48	-69.24
STFEB+ FpgH						
0	20.21	19.87	64.52	44.65	44.65	-10.76
5	101.18	15.57	51.71	36.14	240.77	-52.97
10	666.51	12.20	46.83	34.63	412.89	-77.19
15	1326.21	9.56	42.47	32.91	581.90	-78.99
20	1934.42	7.49	37.45	29.96	737.88	-72.48
25	2523.03	5.87	32.50	26.64	877.76	-62.97
FS40+ FpgH						
0	20.21	21.82	64.52	42.70	42.70	-12.71
5	150.60	17.09	52.41	35.32	231.33	-62.42
10	567.97	13.39	45.73	32.34	398.69	-91.38
15	1049.97	10.49	40.05	29.56	552.06	-108.84
20	1564.47	8.22	34.91	26.69	691.27	-119.09
25	2095.30	6.44	30.20	23.76	815.93	-124.80
FS20+ FpgH						
0	20.21	22.88	64.52	41.64	41.64	-13.77
5	164.03	17.93	52.60	34.68	225.92	-67.83
10	618.92	14.05	46.30	32.25	392.05	-98.02
15	1116.26	11.01	40.63	29.62	545.54	-115.35
20	1637.53	8.62	35.41	26.79	685.21	-125.14
25	2171.48	6.76	30.61	23.86	810.37	-130.35

(1) Income – Cost
(2) Discounted value
(3) Discounted accumulated value

Table 5. Economic efficiency evaluation for schemes using local bull-dams supplemented by importing yearling heifers over 25 years

Year	Genetic progress in milk	Cost (2)	Income (2)	Benefit (1)(2)	NPV of benefit (3)	NPV difference of benefit from CBS (3)
	---kg---	---$X10^6---				
PT/AI+ FylH						
0	0.00	14.01	64.15	50.14	50.14	-5.26
5	85.65	13.64	51.48	37.85	262.43	-31.31
10	386.41	10.69	43.70	33.01	434.84	-55.23
15	822.82	8.37	38.06	29.69	589.96	-70.93
20	1217.49	6.56	32.53	25.97	727.14	-83.21
25	1658.11	5.14	27.86	22.71	847.12	-93.61
LB/AI/NS+ FylH						
0	0.00	14.04	64.15	50.11	50.11	-5.30
5	91.00	13.84	51.56	37.73	261.93	-31.81
10	528.57	10.84	45.29	34.45	437.56	-52.51
15	982.83	8.49	39.46	30.97	599.96	-60.94
20	1485.28	6.66	34.37	27.71	745.04	-65.31
25	1989.33	5.21	29.64	24.42	873.63	-67.10
MOET/AI/NS+ FylH						
0	0.00	14.00	64.15	50.15	50.15	-5.26
5	91.00	13.81	51.56	37.75	262.13	-31.62
10	537.49	10.82	45.39	34.57	437.69	-52.38
15	1123.86	8.48	40.70	32.22	604.24	-56.66
20	1690.62	6.64	35.77	29.13	756.23	-54.12
25	2251.62	5.21	31.05	25.84	892.03	-48.69

(1) Income – Cost
(2) Discounted value
(3) Discounted accumulated value

Table 6. Economic efficiency evaluation for schemes using imported germplasms supplemented by importing yearling heifers over 25 years

Year	Genetic progress in milk	Cost [2]	Income [2]	Benefit [1][2]	NPV of benefit [3]	NPV difference of benefit from CBS [3]
	---kg---	---$X10^6---				
untFEB+FylH						
0	0.00	14.00	64.52	50.52	50.52	-4.89
5	85.65	13.81	51.48	37.67	262.53	-31.22
10	606.67	10.82	46.16	35.34	439.95	-50.12
15	1209.65	8.48	41.45	32.97	610.37	-50.53
20	1771.79	6.64	36.33	29.69	765.54	-44.81
25	2321.09	5.21	31.42	26.21	903.57	-37.16
STFEB+FylH						
0	0.00	17.60	64.15	46.55	46.55	-8.85
5	88.59	13.79	51.53	37.74	251.75	-41.99
10	654.56	10.80	46.70	35.89	430.62	-59.46
15	1315.82	8.46	42.38	33.91	605.24	-55.66
20	1917.93	6.63	37.33	30.70	765.42	-44.93
25	2500.46	5.20	32.38	27.19	908.42	-32.31
FS40+FylH						
0	0.00	19.67	64.15	44.48	44.48	-10.93
5	139.37	15.41	52.25	36.84	241.65	-52.09
10	550.19	12.08	45.53	33.45	415.29	-74.79
15	1029.52	9.46	39.87	30.41	573.47	-87.42
20	1537.29	7.41	34.72	27.31	716.22	-94.13
25	2061.39	5.81	30.02	24.21	843.46	-97.26
FS20+FylH						
0	0.00	20.80	64.15	43.35	43.35	-12.06
5	153.20	16.30	52.45	36.15	235.88	-57.87
10	602.54	12.77	46.11	33.34	408.09	-81.98
15	1097.69	10.01	40.47	30.46	566.30	-94.59
20	1612.23	7.84	35.24	27.40	709.44	-100.91
25	2139.45	6.14	30.44	24.30	837.12	-103.61

(1) Income – Cost

(2) Discounted value

(3) Discounted accumulated value

BIBLIOGRAPHY

BIBLIOGRAPHY

Allaire, F.R., and J.P. Gibson. 1992. Genetic value of herd life adjusted for milk production. J. Dairy Sci.75:1349.

Banos,G., and G.E. Shook. 1990. Genotype by environment interaction and genetic correlations among parities for somatic cell count and milk yield. J. Dairy Sci. 73:2563

Bichard, M., A.H.R. Pease, P.H. Swales, and K.Ozkutuk. 1973. Selection in a population with overlapping generations. Anim. Proc.17:215.

Blake,R.W., F.J.Holmann, J.Gutierrez, and G.F. Cevallos. 1988. Comparative profitability of United States artificial insemination sire in Mexico. J. Dairy Sci. 71:1378.

Boettcher, P.J. L.K. Jairath, K.R Koots and J.C.M. Dekkers. 1997. Effects of interactions between type and milk production on survival traits of Canadian Holsteins. J. Dairy Sci. 80:2984-2995.

Boettcher, P.J., L.B. Hansen, H. Chester-Jones, and C.W. Young. 1993. Responses of yield and conformation to selection for milk in a designed experiment with a control population. J. Dairy Sci. 76:267-273.

Boettcher, P.Reneau, J.,L.B.Hanse, P.M.VanRaden, and C.A.Ernst. 1992. Genetic evaluation of Holstein bulls for somatic cells in milk of daughter. J. Dairy Sci. 75:1127

Boldman, K. G., and T. R. Famula. 1985. Association of sire dystocia transmitting ability with progeny linear type traits in Holsteins. J. Dairy Sci. 68:2052.

Boldman, K.G., A. E. Freeman, B. L. Harris, and A. L. Kuck. 1992. Prediction of sire transmitting abilities for herd-life from transmitting abilities for linear type traits. J. Dairy Sci. 75: 552-563.

Boldman, K.G., A.E. Freeman, B.L.Harris, and A.L. Kuck. 1992. Prediction of sire transmitting ability for herd life from transmitting ability for linear type traits. J. Dairy Sci. 75:552

Brascamp, E.W., J.A.M. van Arendonk, and A.F.Groen. 1993. Economic appraisal of the utilization of genetic markers in dairy cattle breeding. J. Dairy Sci. 76:120~1214.

Burnside, E.B., G.B.Tanson, G.Civati, and E.Dadati. 1992. Observed and theoretical genetic trends in a large dairy population under intensive selection. J. Dairy Sci. 75:2242.

Burke,B.P., and D.A.Funk. 1993. Relationship of linear type traits and herd life under different management system. J. Dairy Sci. 76:2773.

Cassell,B.G. 1986. Maxbull:computerized sire selection for the herd. NCDHIP HANDBOOK.

Cassell,B.G., R.E. Pearson, J.Stoel, and S.Hiemstra. 1990. Relationships between sire evaluations for linear type traits and lifetime relative income from grade and registered daughters. J. Dairy Sci.73: 198.

Chang,C.C., C.Y. Tseng, Z.Y.Chen, and M.C. Chen. 1997. The Holstein Diary Herd Improvement program in Taiwan. Taiwan Livestock Res.Vol.30 (1). 55-65.

Coffey,E.M., W.E.Vinson, and R.E.Pearson. 1986. Potential of somatic cell Concentration in milk as a sire selection Criterion to reduce mastitis in dairy cattle. J. Dairy Sci. 69:2163.

Colleau J.J. 1991. Using embryo sexing within closed mixed multiple ovulation and embryo transfer schemes for selection on dairy cattle. J.Dairy Sci. 74: 3973-3984.

Colleau,J.J. and Le Ban Duval, E. A simulation study of selection methods to improve mastitis resistance of dairy cows. J. Dairy Sci. 78 : 659-671.

Cue, R.J., and J. F. Hayes. 1985. Correlations of various direct and maternal effects for calving ease. J. Dairy Sci. 68:374.

Dadati,F.B., B.W. Kennedy, and E.B. Bumude.1985. Relationships between conformation and reproduction in Holstein cows: type and calving performance. J. Dairy Sci. 68:2639.

De Haan, M.H.A., B.G. Cassell, R.E. Pearson , and B.B. Smith. 1992. Relationship between net income, days of productive life, productive life, production, and linear type traits in grade and registered Holstein. J. Dairy Sci.75:3553.

Dekkers, J.C.M. and Shook, G.E. 1990. Genetic and economic evaluation of nucleus breeding schemes for commercial artificial insemination firms. J.Dairy Sci. 73:1920-1937.

Dekkers,J.C.M. 1993. Theoretical basis of genetic parameters of herd life and effect on response to selection. J. Dairy Sci.76:1433.

Dekkers,J.C.M., L.K. Jairath, and B.H. Lawrence. 1994. Relationship between sire genetic evaluations for conformation and functional herd life of daughters. J. Dairy Sci.77:844.

Dekkers, C. M. 1994. Optimal breeding strategies for calving ease. J. Dairy Sci. 77: 3441 –3453

Dekkers.J.C.M.1992. Structure of breeding programs to capitalize on reproductive technology for genetic improvement. J. Dairy Sci. 75:2880-2891.

Dekkers, J.C.M. and G.E. Shook.1990. Economic evaluation of alternative breeding programs for commercial artificial insemination firms. J. Dairy Sci. 73:1902-1919.

Dekkers, J.C.M. and G.E. Shook.1990. Genetic and economic evaluation of nucleus breeding schemes for commercial artificial insemination firms. J. Dairy Sci. 73:1920-1937.

Dentine,M.R., B.T. McDaniel, and H.D.Norman. 1987. Evaluation of sires for traits associated with herdlife of grade and registered Holstein cattle. J. Dairy Sci. 70:2623.

Ducroco,V. and Quaas,R.L. 1988. Prediction of genetic response to truncation selection across generations. J.Dairy Sci. 71:2543-2553.

Ducrocq, V.,R.L. Quaas., E.J. Pollak, and G. Casella. 1988. Length of productive life of dairy cows. 2. Variance component estimation and sire evaluation. J.Dairy Sci. 71:3071.

Emanuelson,U., B. Danell, and J. Philipsson.1988. Genetic parameters for clinical mastitis, Somatic cell counts ,and milk production estimated by multiple-trait restricted maximum likelihood. J. Dairy Sci.71:467.

Everett, R.W. 1975. Income over investment in semen. J. Dairy Sci. 58:1717.

Everett, R. W., J. F. Keown, and E. E. Clapp. 1976. Relationships among type, production, and stayability in Holsteins. J. Dairy Sci. 59:1505.

Everett, R.W. 1984. Impact of genetic manipulation. J. Dairy Sci. 67:2812-2818.

Falconer, D. S. 1989. Introduction to quantitative genetics. 3rd ed. Academic Press, Longman, Hong Kong.

Foster, W. W., A. E. Freeman, and P. J. Berger. 1988. Linear type trait analysis with genetic parameter estimation. J. Dairy Sci. 7t:223,

Henderson, C. R. 1976. A simple method for computing the inverse of a numerator relationship matrix used in prediction of breeding values. Biometrics 32: 69.

Heuven,H.C.M., H. Bovenhuis, and R.D. Politiek. 1988. Inheritance of somatic cell count and its genetic relationship with milk and composition in Holstein. J. Dairy Sci. 65:843.

Hill, W.G. 1971. Investment appraisal for national breeding programs. Anim. Prod. 13:37.

Hill, W.G. 1974. Prediction and evaluation of response to selection with overlapping generations . Anim. Prod.18:117.

Holmann,F., R.W. Blake, R.A. Milligan, R.Barker,P. A. Oltenacu, and M. V. Hahn. 1990. Economic returns from United States artificial insemination sires in Holstein herds in Colombia, Mexico, and Venezuela. J. Dairy Sci. 73:2179.

Hopkins, I.R., and J.W. James. 1977. Some optimum selection strategies and age structures with overlapping generations. Anim. Prod. 25:111.

Hopkins, I.R. and J.W. James. 1979. Genetic responses in the early years of selection programmes using genetic differences between generations. Anim. Prod. 28:65.

Jairath, L. ,J.C.M. Dekkers, L.R. Schaeffer, Z. Liu, E.B. Burnside and B. Kolstad 1998. Genetic evaluation for herd life in Canada.. J. Dairy Sci. 81:550-562.

Juga, J. and Maki-Tanila, A. 1987. Genetic change in a nucleus breeding dairy herd using embryo transfer. Acta, 37:511- 519.

Keller, D. S. and Teepker. 1990. Effect of variability in response to superovulation on donor cow selection differentials in nucleus breeding schemes. J. Dairy Sci. 73:549

Kennedy,B.W., M.S. Sethar, J.E. Moxley, and B.R. Downey. 1982. Heritability of somatic cell count and its relationship with milk yield a composition in Holsteins. J.Dairy Sci. 65:843.

Koops, W. J., M. Grossman, and J.H.G. den Daas. 1995. A model for reproductive efficiency of dairy bulls. J. Dairy Sci. 78:921.

Kuhn, M.T. ,P.J. Boettcher and A.E. Freeman.1994. Potential biases in predicted transmitting abilities of females from preferential treatment. J. Dairy Sci. 77:2428-2437.

Lee, K. L., A. B. Freeman and L. P. Johnson.1985. Estimation of genetic trend in the registered Holstein cattle population. J. Dairy Sci. 68:2629.

Lindhe, B. 1968. Model simulation of AI breeding within a dual purpose breed of cattle. Acta Agric. Scand. 18:33.

Jeon, G.J., I.V. Mao, j. Jensen, and T. A. Ferris. Stochastic modeling of multiple ovulation and embryos transfer breeding schemes in small closed dairy cattle population. J. Dairy Sci. 73:1938-1944.

Louis, M.M., C. Smith and J.C.M. Dekkers. 1993. MOET results from a dispersed hybrid nucleus programme in dairy cattle. Anim. Prod. 57:369-378.

Mao. I.L., M.C. Dong and C.E. Meadows. Selection of bulls for progeny testing using pedigree indices and characteristics of potential bull-dam' erds. 1991. J. Dairy Sci. 74: 2747.

Meuwissen, T.H.E. 1991. Expectation and variance of genetic gain in open and closed nucleus and progeny testing schemes. Anim. Prod. 53:133.

Meuwissen,T.H.E., and J.A.M. Van Arendonk. 1992. Potential improvements in rate of genetic gain from marker- assisted selection in dairy cattle breeding schemes. J. Dairy Sci. 75: 1651- 1659.

Meyer, K., and C. Smith. 1990. Comparison of theoretical and simulated equilibrium genetic response rates with progeny testing in dairy cattle. Anim. Prod. 50: 207.

Misztal, I., T.J. Lawlor, T. H. Short, and P. M. VanRaden. 1992. Multiple-trait estimation of variance components of yield and type traits using an animal model. J. Dairy Sci. 75:544.

Mocquot J.C., 1988. Sire-Son and dam paths: research geneticist's view. J. Dairy Sci. 71:1972 -1981.

Monardes, H. G., R. I. Cue, and J. F. Hayes. 1990. Correlations between udder conformation traits and somatic cell Count in Canadian Holstein cows. J. Dairy Sci. 73:1337.

Mopofu, N., Smith, C. and Burnside. E. B. 1993. Breeding Strategies for genetic improvement of dairy cattle in Zimbabwe. 1.genetic evaluation J.Dairy Sci. 76:1163-1172.

Mopofu, N., Smith, C., Van Vuuren, W. and Burnside, E. B. 1993b. Breeding strategies for genetic improvement of dairy cattle in Zimbabwe. 2. Economic evaluation. J. Dairy Sci. 76:1173-1181.

Nicholas, F.W., and C. Smith. 1983. Increased rates of genetic change in dairy cattle by embryo transfer and splitting. Anim. Prod. 36:341.

Norman, H. D., and L. D. Van Vleck. 1972. Relationship of first lactation production and type traits with lifetime performance. J. Dairy Sci. 55:1726.

Rendel J. M.and Robertson . 1950. Estimation of genetic change in milk yield by selection in a close herd of dairy cattle. J. Genetic 50: 1-8.

Rogers. G.W., and B.T. McDaniel. 1989. The usefulness of selection for yield and functional type traits. J. Dairy Sci. 72:187.

Rogers,G.W., B.T.McDaneil, M.R.Dentine, and D.A.Funk. 1989.Genetic correlation between survival and Linear type traits measured in first lactation .j Dairy Sci. 72:523.

Rogers,G.W., G.L. Hargrove, T.J. Lawlor,Jr., and J.L. Ebersole.1991. Correlations among linear type traits and somatic cell count counts. J. Dairy Sci.74:1087.

Rogers. G.M.,B. T. McDaniel, M. R. Denteine, and L.P. Johnson . 1988. Relationship among survival rates, predicted differences for yield, and linear type traits. J. Dairy Sci. 71:214.

Rogers, G.W. 1993. Index selection using milk yield, somatic cell score, udder depth, teat placement, and foot angle. J.Dairy Sci. 76:664

Ruane, J., and J. J. Colleau. 1996. Marker-assisted selection for a sex-limited character in a nucleus breeding population. J. Dairy Sci. 79:1666-1678.

SAS® User's Guide: Statistics, Version 6.03 Edition. 1997. SAS Inst., Inc., Cary, NC.

Schaeffer,L.R., and J.Jamrozik.1996. Multiple-trait prediction of lactation yields for dairy cows. J. Dairy Sci. 79:2044-2055.

Schaeffer,L.R., R.Reents and J.Jamrozik. 1996. Factors influencing international comparisons of dairy sires. J. Dairy Sci. 79:1108-1116.

Schutz, M.M., L.B. Hansen, G.R. Steuernagel, and J.K. Reneau. 1990. Genetic parameters for somatic cells, protein and fat in milk of Holsteins. J. Dairy Sci. 73:494

Schutz, M.M., L.B. Hansen, G, R. Steuernagel, and A.L.Kuck. 1990. Variation of milk, fat, and somatic cells for dairy cattle. J Dairy Sci. 73:484.

Schutz, M.M.1994. Genetic evaluation of somatic cell score for United State dairy cattle. J. Dairy SCi. 77:2113.

Schutz, M.M., P.M. VanRaden, P.J. Boettcher, and L. B. Hansen. 1993. Relationship of somatic cell score and linear type trait evaluation of Holstein sires. J. Dairy Sci. 76:284.

Schutz,M.M., and P.M.VanRaden, and G.R.Wiggans..1994. Genetic variation in lactation means of somatic cell scores for six breeds of dairy cattle. J.Dairy Sci.77:648.

Schutz,M.M., P.M.Vanraden, G.R.Wiggans, and H.D.Norman. 1995. Standardization of lactation means of somatic cell scores for calculation of genetic evaluations. J. Dairy Sci.78:1843.

Seykora, A.J., and B.T. McDaniel. 1986. Genetics statistics and relationships of teat and udder traits, somatic cell counts, and milk production. J. Dairy Sci. 69:2395

Shook, G. E. 1989. Selection for disease resistance. J. Dairy Sci. 72:1349.

Shook,G.E., and M.M.Schutz.1994. Selection on Somatic cell score to improve resistance to mastitis in Unite States. J. Dairy Sci. 77:648

Short, T.H., and T.J. Lawlor. 1992. Genetic parameters of conformation traits, milk yield, and herd life in Holsteins. J. Dairy Sci.75:1987.

Sieber,M., A.F.Freeman, and P.N. Hinz. 1987. Factor analysis for evaluating relationships between first lactation type scores and production data of Holstein dairy cows. J. Dairy Sci. 70:1018.

Sivanadian,B., M.M. Lohuis and J.C.M. Dekkers. 1998. Expected genetic responses from selection indexes for Canadian dairy cattle under present and future milk pricing systems. Can. J. Anim. Sci. 78:157-165.

Smith, C. 1978. The effect of inflation and form of investment on the estimated value of genetic improvement in farm livestock. Anim. Prod. 26:101.

Smith,C., and J. Ruane. 1987. Use of sib testing as a supplement to progeny testing to improve the genetic merit of commercial semen in dairy cattle. Can. J. Anim. Sci. 67:985.

Smith C., and M Quinton.1993. The effect of selection in sublines and crossing on genetic response and inbreeding. J.Anim.Sci. 71: 2631-8

Spelman,R.J., and D.J.Gairick. 1997. Utilization of marker assisted selection in a commercial dairy cow population. Livest. Prod. Sci. 47:139-147.

Spelman,H.J., and D.J. Garrick. 1998. Genetic and economic responses for with-in family Marker-Assisted Selection in dairy cattle breeding schemes. J. Dairy Sci. 81:2942-2950.

Standberg,E., and G.E. Shook. 1989. Genetic and economic responses to breeding program that consider mastitis. J.Dairy Sci. 72.2136.

Stanton,T.L., R.W. Blake, and R.L. Quaas.1991. Response to selection of United States Holstein Sire in Latin America. J.Dairy Sci.74:651.

Strandberg E., E Shook. 1989. Genetic and economic responses to breeding programs that consider mastitis. J.Dairy-Sci. 72: 2136-42

Uribe, H.A., B.W. Kennedy, S.W. Martin and D.F. Kelton. 1995. Genetic parameters for common health disorders of Holstein cows. J. Dairy Sci. 78:421-430.

VanRaden, P..M., E.L.Jensen, T.J.Lawlor and D.A.Funk. 1990. Prediction of transmitting abilities for Holstein type traits. J.Dairy Sci. 73:191.

VanRanden P.M.1991. Derivation, calculation, and use of national animal model information. J. Dairy Sci. 74:2737-2746

Van Arendonk. 1991. Use of profit equations to determine relative economic value of dairy cattle herd life and production from field data. J. Dairy Sci. 74:1101.

VanRaden, P.M., E.L. Jensen, T.J. Lowlier, and D.A.Funk. 1990. Prediction of transmitting abilities for Holstein type traits. J.Dairy Sci.73:191.

VanRaden, P.M., G.R. Wiggans, and C.A.Ernst.1991. Expansion of projected lactation yield to stabilize genetic variance, J. Dairy Sci.74:4344.

VanRaden, P.M., and E.J.H. Klaaskate.1993. Genetic evaluation of length of productive life include n predicted longevity of live cows. J.Dairy Sci. 76:2758.

Vanraden P.M. and G.R. Wiggans. 1995. Productive life evaluation : calculation, accuracy, and economic value. J Dairy Sci.78:631.

VanRaden, P.M., and A.E Freeman. 1985. Potential gains from producing bulls with only sires as parents. J. Dairy Sci. 68:1425.

VanRaden, P.M., and E.J.H. Klaskate. 1993. Genetic evaluation of length of productive life including predicted longevity of live cows. J. Dairy Sci. 76:2758-2764.

Van Tassell, C.P., and L.D. Van Vleck. 1991. Estimates of genetic selection differentials and generation intervals for four paths of selection. J. Dairy Sci. 74:1078.

Van Vleck, L.D., R.A. Welstell., and J.C. Schneider. 1986. Genetic change in milk yield estimated from simultaneous genetic evaluations of bulls and cows. J. Dairy Sci. 69:2963.

Weigel. K.A., T. J. Lawlor, JR., P. M. VanRaden, and G. R. Wggans. 1996. Use of Linear Type and Production Data to Supplement Early Predicted Transmitting Abilities for Productive Life. J. Dairy Sci. 81:2040-2044

Wiggans,G.R. and G.E. Shook.1987. A lactation measure of somatic cell count. J. Dairy Sci.70 : 2666.

Welper, R.D. and A.E. Freeman. 1992. Genetic parameters for yield traits of Holstein, including lactose and somatic cell score. J.Dairy Sci. 75:1342

Weigel,D.J., B.G. Cassell, and R.E. Pearson. 1995. Relative genetic merit and effectiveness of selection of young sires for artificial insemination. J. Dairy Sci. 78:2481

Weller, J.I. and D. Gianola. 1989. Models for genetic analysis of dystocia and calf mortality. J. Dairy Sci. 72:2633.

Westell R.A.; L.D.Van-Vleck.1987. Simultaneous genetic evaluation of sires and cows for a large population of dairy cattle. J. Dairy Sci. 70: 1006-17

Westell, R. A., R.L. Quaas, and L. D. Van Vleck.1988. Genetic groups in animal model. J. Dairy Sci. 71:1310.

Wiggans, G.R., P.M. VanRaden, and R.L. Powell. 1992. A method for combining United States and Canadian bull evaluations. J. Dairy Sci. 75:2834-2839.

Wiggans, G.R and M.E.Goddard.1997. A computationally feasible test day model for genetic evaluation of yield traits in the United States. J.Dairy Sci. 80: 1795-1800.

Woolliams J.A. and Smith C. 1988. The value of indicator traits in the genetic improvement of dairy cattle. Anim. Prod. 46:333-345

Woolliams, J.A. 1989. The value of cloning in MOET nucleus breeding schemes for dairy cattle. Anim. Prod. 48:31- 35.

Woolliams, J.A.and Wilmut I. 1989. Embryo manipulation in cattle breeding and production. Anim. Prod. 48:330.

Young, C. W. and J. G. Leece. 1960. Genetic and phenotypic relationships between clinical mastitis, laboratory criteria, and udder height. J. Dairy Sci. 43:54.

Zhang, W. C., J.C.M. Dekkers, G. Banos, and E.B. Burnside. 1994. Adjustment factors and genetic evaluation for somatic cell score and relationships with other traits of Canadian