

National Genetic Improvement Programs: Challenges and Rewards

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Introduction

National genetic improvement programs are the premier source of information and genetic evaluation of animals in large beef and dairy cattle populations. The structure of these programs takes a variety of forms depending on the size and distribution of the national population and the type of cattle (beef, dairy, dual-purpose). In general, however, the collection and maintenance of the information is carried out by a government organization or a non-profit cattlemen organization, and the genetic evaluation is in the hands of the same government institution or non-profit organization, or a contracted university.

Basic and applied research for national genetic evaluation programs comes from a wide range of sources: universities and research stations, government institutions, and private industry. In recent years private investment by industry and development of new genetic evaluation traits and procedures has increased substantially. This private investment is likely to contribute in a major way to shape the future of national genetic improvement programs in both beef and dairy cattle populations around the world.

The purpose of this presentation is to discuss: 1) the reasons why national genetic evaluations are needed, 2) the challenges a country faces when developing national cattle genetic evaluations, and 3) the rewards to be expected from the development of efficient national genetic evaluation programs.

Why Are National Genetic Evaluations Needed?

National genetic evaluations are needed because they: 1) provide a uniform genetic comparison tool across a country, 2) maximize the accuracy of prediction of genetic values and animal rankings, 3) are an essential selection and mating tool for unibreed and multibreed populations, and 4) are a marketing tool that increases the economic value of the evaluated animals.

Uniform Genetic Comparison Tool. Unibreed and multibreed EPD (expected progeny differences) allow the comparison of calves, sires, and dams across all regions of a country if the population is genetically connected. If the population has only one breed

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(unibreed) connectedness can be achieved by using sires in two or more contemporary groups. Contemporary groups are simply groups of animals of similar age and sex that live in some area and are managed alike. Connectedness in multibreed populations (populations composed of purebred and crossbred animals that interbreed) can be achieved in a similar fashion, i.e., through the presence of common sires in two or more contemporary groups. To minimize the likelihood of genotype by environment interaction, sires should be mated across all breed groups of dams within a contemporary group.

Maximize the Accuracy of Prediction of Genetic Values and Animal Rankings. The larger the amount of information used for the estimation of genetic parameters and the prediction of genetic values, the more accurate predicted genetic values and sire rankings will be. Thus, given a particular genetic model, national genetic predictions will be more accurate than regional or local genetic predictions. A national genetic model should account for all topographical and climatological effects within a country. If unfeasible, some regional genetic evaluations may need to be considered.

Selection and Mating Tool for Unibreed and Multibreed Populations. National genetic predictions are an essential tool for accurate selection and mating decisions. Because they provide an objective prediction of the genetic values of parents and progeny, the effectiveness of selection and mating plans can be assessed both genetically and economically, and modifications to future plans can be made accordingly.

Marketing Tool. National genetic evaluations will increase the economic value of animals with genetic predictions. Cattlemen in many countries now demand information on predicting genetic values before purchasing livestock or semen. National genetic predictions provide an objective measure of the genetic worth of an animal as a prospective parent within the range of the national population. When buying semen or livestock both genetic prediction and accuracy values need to be considered. Accuracies will indicate to buyers how close sire unibreed and multibreed EPD are to the mean genetic values of their future progeny.

What are the challenges?

The installation of a well-structured national genetic evaluation system will face at least the following challenges: 1) the building of a well-connected population, 2) the development of adequate nutrition, management, and health programs, 3) the creation of a data collection and maintenance system, 4) the construction of a genetic evaluation system, 5) to provide continuity and dynamic goals, and 6) to have flexible organization and resources.

Well-Connected Population. The basis of a national genetic evaluation system is a dataset coming from a well-connected national population. As indicated above, a population is connected through the use of sires in two or more contemporary groups. If a national population is multibreed, then contemporary groups will be multibreed, and

sires should be preferably mated to dams of all breed compositions within each contemporary group.

The national beef and dairy populations of Thailand are multibreed. Both populations have *Bos taurus* and *Bos indicus* breeds represented. The mating system in the dairy population is essentially an incomplete upgrade to Holstein starting from a female base population formed by Thai Native, Thai Brahman, Red Sindhi, and other minor breeds. The mating system for the beef population appears to be a less formal crossbreeding system involving breeds such as Charolais, Simmental, Limousin, Brangus, Brahman, Thai Brahman, Thai Native, and Red Sindhi. Both purebred and crossbred sires and dams have been used in both populations, thus both populations are multibreed. Because only a fraction of all potential mating types between breed groups are represented in both populations, they are classified as incomplete multibreed populations.

In the dairy multibreed population recorded at the Dairy Promotion Organization (DPO), nearly all the sires used have been Holstein or high percentage Holstein (above 75% Holstein). As an illustration, **Figure 1** shows the numbers of sires and dams from a 1991-2000 edited DPO multibreed data set.

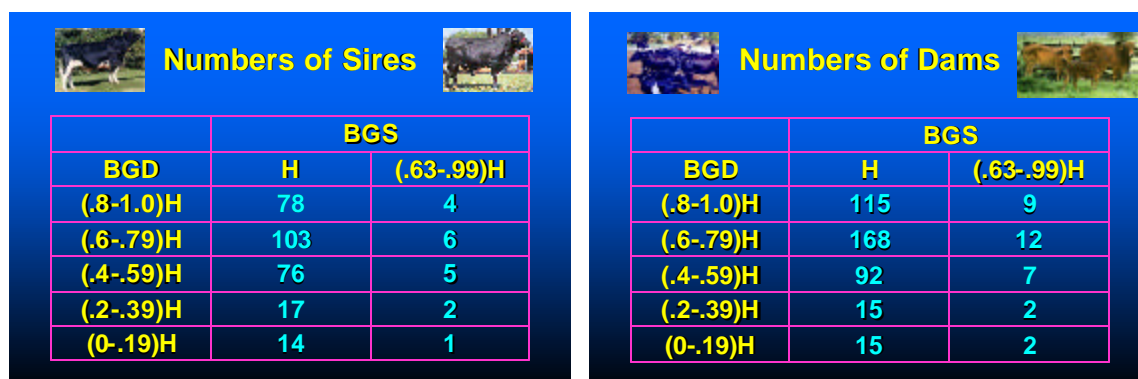


Figure 1. Number of sires and dams from a 1991-2000 edited DPO data set

Because of the tremendous use of Holstein sires across the DPO population, the 1991-2000 edited DPO dataset was well connected.

Adequate Nutrition, Management, and Health. When a population is considered for genetic improvement, changes in nutrition, management, and health programs in the population need to be concurrently considered. In addition, genetic and environmental plans need to be evaluated from an economic and human perspective. Geneticists and cattlemen need to be aware that changes in nutrition, management, and health may be required for improved animals to perform at the expected higher levels. Genetic improvement needs always be considered as part of a production system, and never in isolation.

Data Collection and Maintenance System. A sound and complete data set is the foundation of a national genetic evaluation program. A data collection and maintenance

system to be successful must: 1) have well-trained and motivated personnel, 2) have up-to-date equipment and facilities, 3) collect individual animal data on reproduction, production, health, breed composition, and complete pedigree (individual, sire, dam), 4) include the date (and time if needed) of each piece of data collected for each animal, 5) collect data on traits for current and future genetic evaluations, 6) be responsive to changes in biology and technology, 7) retrain personnel periodically, and 8) upgrade equipment, particularly computer hardware and software, periodically.

Current Thai field data sets are small to medium in size. However, they have the potential to become large in a short period of time. Thus, plans for data collection and maintenance must be aimed at large-size data sets.

Genetic Evaluation System. The form that a genetic evaluation system takes in a population depends on: 1) available resources (human, hardware, software), 2) the structure and size of the population (large, unbalanced, unibreed, multibreed), 3) the traits targeted for selection (discrete, continuous), 4) the genetic-statistical models and procedures used to obtain predictions of individual animal genetic values (linear, nonlinear), and 5) computational strategies (direct, iterative).

Assuming appropriate human, hardware, and software resources are available, the steps involved in designing a genetic evaluation system in a multibreed dairy cattle population could be as follows: 1) to identify the relevant genetic and environmental effects that may be present in a potential target trait, and to make a diagram of their genetic and environmental relationships (**Figure 2**), 2) to make computer charts of these relevant genetic and environmental effects (**Figure 3**), 3) to work out potential models and computational strategies, and to decide on a final genetic-statistical model (**Figure 4**), 4) to define the additive and nonadditive genetic bases and the animal genetic predictions to be computed (**Figure 5**), 5) to present population results in tables and charts that are informative and easy to understand (**Figure 6**), and 6) to publish animal genetic predictions in a format that is easily accessible (paper, electronic).

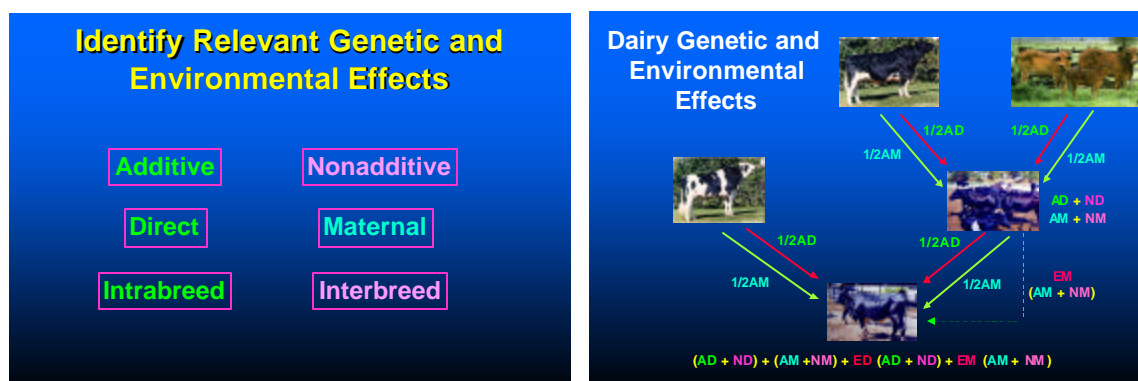


Figure 2. Genetic and environmental effects for potential target traits and their relationships

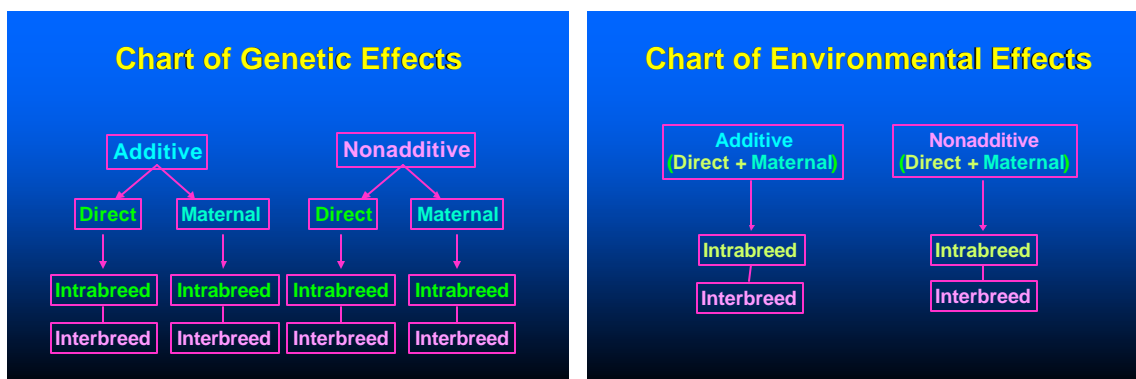


Figure 3. Flowchart of genetic and environmental effects for potential target traits

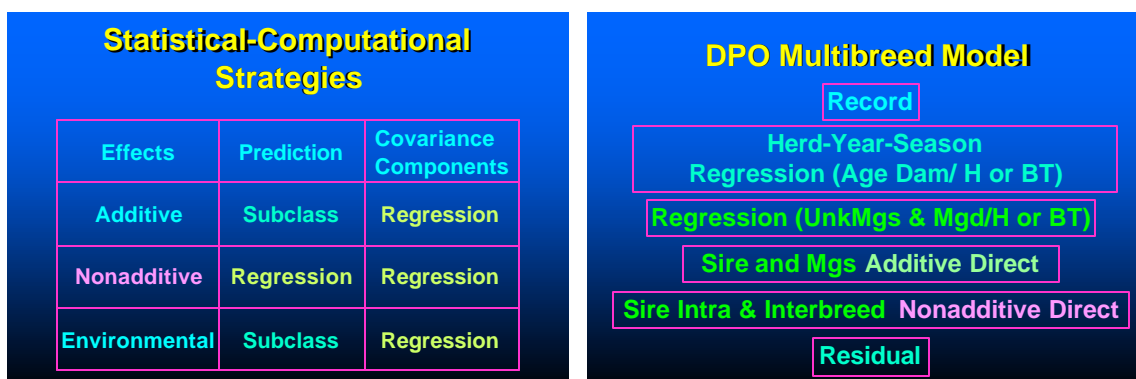


Figure 4. Potential models and computing strategies, and final genetic-statistical model

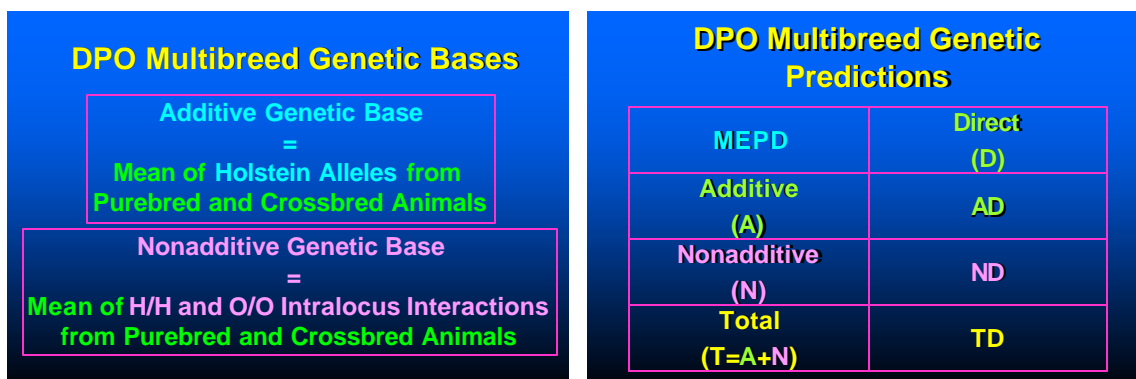


Figure 5. Multibreed genetic bases and genetic predictions

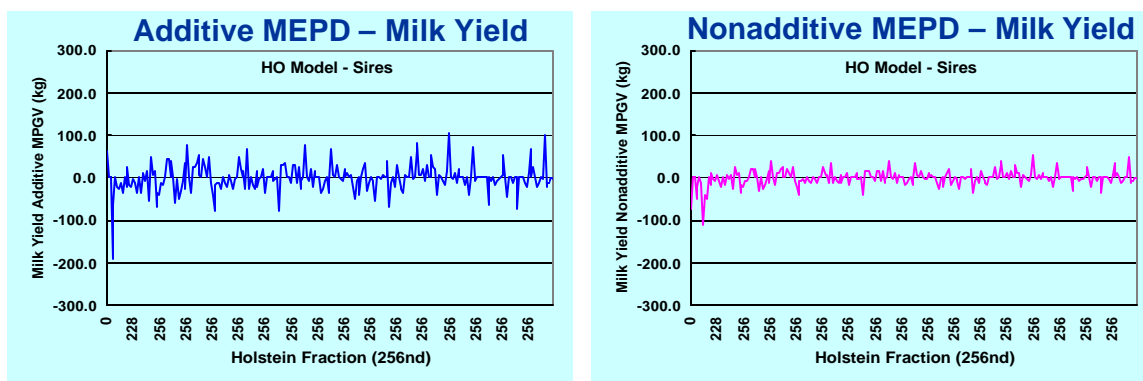


Figure 6. Charts of additive and nonadditive multibreed genetic predictions for a 1991-2000 edited DPO dataset

Publication of unbreed EPD is usually done on paper only for a subset of all evaluated animals, and the complete version can be accessed electronically through the internet. Because of the large number of nonadditive and total genetic predictions that could exist in a multibreed population, electronic publication seems the most reasonable alternative. Perhaps short lists (e.g., top 5%) of the best animals for particular traits could also be published on paper and distributed to cattlemen. In addition, a mating service program that accounts for additive and nonadditive genetic effects should be made available for use through the internet.

Continuity and Dynamic Goals. Moving the mean of a cattle population in some direction can take many years. Thus, because genetic improvement programs are long-term affairs, continuity of purpose is essential for their success. Resources, target traits, and selection objectives must be kept in place for the necessary length of time to accomplish the intended goals. Global and local economic fluctuations may make long-term improvement goals unreliable or plainly unfeasible. Thus, genetic improvement objectives must have dynamic goals that, at least, will achieve partial success if there were insufficient time and/or resources to fully accomplish the intended objectives. To this end, it would seem advisable to devise genetic improvement plans with several layers (e.g., primary, secondary, tertiary) of related target traits. With the an increasingly large availability of new biological traits, this may be a reasonable approach to implement in the near future. Genetic evaluation systems will need to become more flexible and probably systemic in nature to accommodate all the considered options.

Genetic improvement programs should always be integrated into production and economic programs. It is doubtful that a genetic improvement program will be supported by cattlemen unless it is part of a realistic production and economic system that they can understand. Consideration of the human factor cannot be overemphasized.

Flexible Organization and Resources. Globalization has dramatically increased the speed of biological, quantitative, and economic changes around the world. Its primary effect has been that for programs of any kind to survive and flourish they must be flexible, responsive to environmental changes, and capable of allocating sufficient resources. The speed and degree of globalization is bound to increase in the future.

Thus, organizations in charge of genetic, production, and economic programs within countries will need to become increasingly flexible, and allocate the necessary resources to match global production and economic challenges. Layering of target traits, inclusion of a wider variety of biological and synthetic measures as target traits, new and(or) additional populational sampling procedures, new and(or) improved genetic-statistical and systemic methodologies, and better hardware and software will be needed to keep up with the upcoming changes.

New alliances and cooperatives are being formed in the cattle industry in the USA and other countries. These organizations are similar to those already in place in the swine and poultry industry. Private companies are producing enormous amounts of biological data at enormous costs. Universities are forming research-development partnerships with private organizations. All these developments will affect the structure of future national genetic improvement programs, and their relationship with global genetic evaluation systems.

What are the rewards?

A successful national genetic improvement program will bring about the following benefits: 1) the population will have been moved in the desired direction, i.e., target traits will show genetic and phenotypic trends in the direction of the selection pressure, 2) the population will have a complete national database with information on genetic, production, health, and economic information that can be used for current and retrospective studies, 3) objective decisions will be able to be made on genetic, management, economics, and other issues, 4) realistic projections genetic improvement, management, and economic plans based of a reliable source of information will be able to be made, 5) the population will show improvements in nutrition, management, and health in association with genetic improvements, and 6) a national organization will have been created that is responsive to local and global market changes.

Genetic and Phenotypic Trends. Genetic trends are the result of selection pressure on targets traits in a particular direction (e.g., towards higher milk productions), whereas phenotypic trends include both genetic changes and environmental improvements (e.g., in nutrition, management, health). Genetic changes will accumulate in the population over time. Improvements in environmental conditions of animals will need to be not only maintained, but also enhanced as the population moves towards higher levels of production. Whether these higher production levels will be economically advantageous will depend on the local and, increasingly, global economic conditions. Thus, a dynamic genetic-environmental-economic goal needs to be implemented to maintain an economically feasible national genetic improvement program.

As an illustration, the genetic trends of a 1991-2000 edited DPO dataset and the 1961-2002 Holstein population of the USA are shown for milk yield (**Figure 7**), and fat yield (**Figure 8**). The flatness of the genetic trends for milk and fat yields between 1988 and 1997 of the Thai DPO dataset is comparable to that shown by the USA Holstein

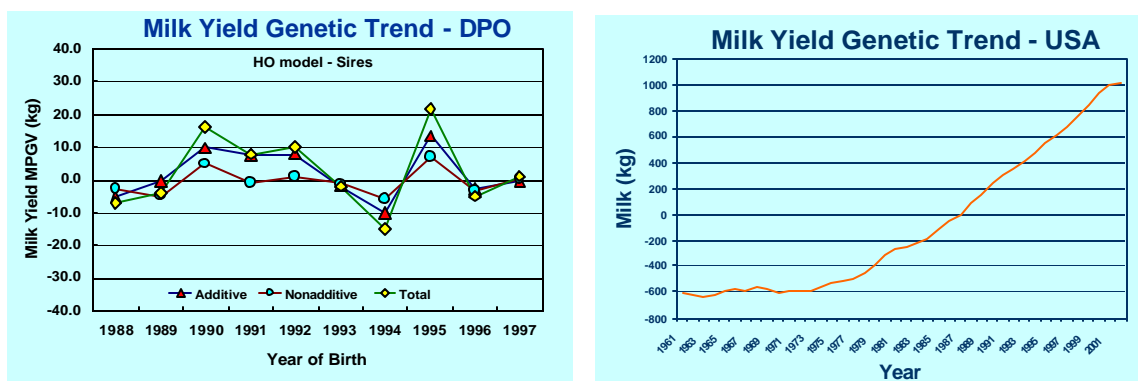


Figure 7. Milk yield genetic trend in a 1991-2000 edited DPO dataset and in the USA Holstein population

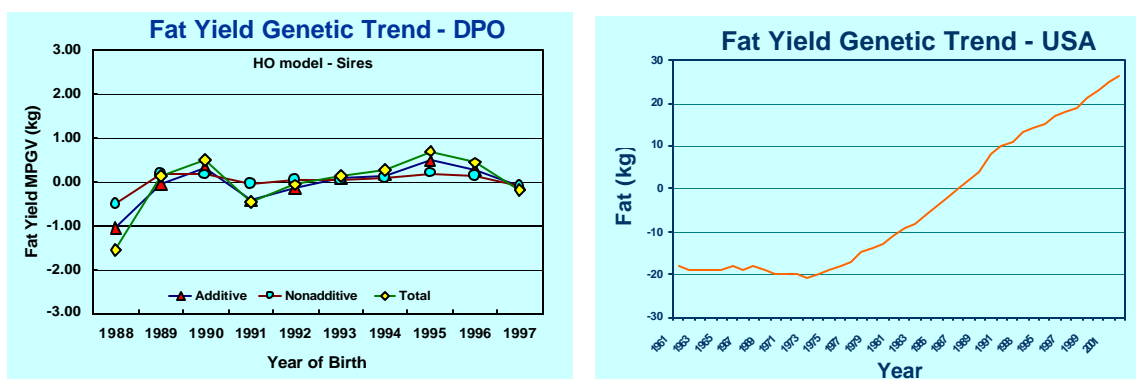


Figure 7. Milk yield genetic trend in a 1991-2000 edited DPO dataset and in the USA Holstein population

population between 1961 and 1977. Higher levels of accuracy of genetic predictions, probably due to larger datasets and improved genetic evaluation procedures may have been largely responsible for the substantially better milk and fat yield genetic trends after 1977. Milk and fat yield genetic trends in Thailand could be improved by: 1) including dairy information from the whole country, 2) improving the system of data collection and maintenance of data such that a substantially larger and reliable dataset can be available for genetic evaluation, 3) using up-to-date genetic-statistical methods and models, and 4) increasing the numbers of progeny from the best sires and dams in the population. Not only selection of animals in Thailand, but also importation of genetic material (semen, sires, dams) will have an impact on future genetic trends of the Thai dairy multibreed population.

Well-Documented Population. Having a complete database for the national cattle population of Thailand will be of enormous benefit to the country. Information from this national database will prove invaluable for research in a variety of areas (e.g., economics, production, nutrition, reproduction, management, genetics), to develop national genetic,

production and economic plans, to conduct feasibility studies, etc. Genetic improvement research and development will be only one of many areas using the collected information.

Improvements in Nutrition, Management, and Health. Higher milk production levels are usually associated with higher levels of nutrition, management, and health conditions in a production system. The development of a national genetic improvement program will generate an associated increase in the level of nutrition, management, and health conditions at least in some segments of the Thai cattle population. However, this is a cost-benefit problem, increases in the use of resources will eventually cease to be economically advantageous. Because of the variety of local geographic and economic conditions, several economically advantageous genetic-nutrition-management-health levels may eventually end up coexisting in Thailand. This variety of genetic and environmental conditions will need to be accommodated in the modeling strategy of the national genetic evaluation program. A national multibreed dataset will be able to be analyzed as a single dataset if data from the contemporary groups are connected through sires, and sires are mated to dams of all breed compositions within multibreed contemporary groups.

Objective Decisions: Genetic, Production, Economic. The existence of a complete database covering all phases of the production process as well as economic aspects of the Thai national cattle population will permit the use of systems software to make decisions in an objective manner. Information from the national cattle database will allow the study of different genetic-production-economic scenarios and the evaluation of their outcomes. Further, once a development plan is implemented, as soon as new data becomes available, it will be able to be evaluated and appropriately corrected on a timely basis. In other words, the chosen national genetic-production-economic system will be able to be fine-tuned iteratively based on its own performance.

Realistic Projections. A national database will permit realistic projections, thus decreasing the risk of failure by simulating and studying different scenarios before one is implemented. Realistic projections will: 1) produce more realistic expectations, 2) enable planners to reduce the risk level by minimizing probable differences between projected and actual results, 3) increase the level of trust and cooperation among participants (cattlemen, researchers, planners), 4) permit a better allocation of resources, and 5) decrease costs.

Organization Responsive to Market Changes. An organization that considers all the aspects discussed above will be able to quickly respond to changes in the production and economic environments. To be flexible and responsive however, such an organization will either have to be very diversified, or it will have to form alliances and partnerships to do research and development in critical areas. One such partnership would be with universities to pursue research and development of genetic improvement programs. Both partnerships and alliances currently exist in the USA and other countries. To be successful, these organizations need to be nimble and help facilitate research, development, and marketing of new technologies. Responsiveness, flexibility, and innovation will all help keep the cattle industry competitive.

Final Thoughts

The basic structure for a national dairy cattle genetic evaluation appears to be already in place in Thailand. Changes and new developments will be needed to include information and participation from cattlemen from all regions in Thailand. Thus, some reorganization of existing entities, formation of alliances with researchers at universities and experimental stations, partnerships with cattlemen organizations, all with the purpose of strengthening and increasing the level of cooperation in research and development in cattle genetic improvement programs seem advisable to be explored. The scope and complexity of the task of creating an effective national improvement program well integrated into the economic structure of the country makes it a long-term project, whose timetable will be measured in years. The similarity in structure of the Thai beef and dairy populations and the fact that many cattlemen will have beef and dairy animals in their farms suggests that the Thai national genetic improvement program should include both beef and dairy cattle.

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