SIB-TESTING WITH EMBRYO TRANSFER IN DAIRY CATTLE IMPROVEMENT - DESIGN OF EXPERIMENT

A.J. LEE, A.J. MCALLISTER and C.Y. LIN, CANADA
Animal Research Centre, Agriculture Canada
Ottawa, Ontario, CANADA, K1A 0C6

SUMMARY

A dairy cattle breeding project based on the principles of Nicholas and Smith (1983) is described. The 450 milking cow herd at Ottawa includes 85 Ayrshire based A line, 185 Holstein H line and 180 C line crossbreds from the A and H parental lines. Effects of genotype of embryo, genotype of surrogate dam and their interaction on lifetime performance will be examined with crossbred embryos and Holstein embryos from selected donor cows in the industry at large transferred to A, H and C line recipients. The population derived from the Holstein embryos will be the foundation population for experimental evaluation of the sib-testing breeding scheme. One male from each donor Holstein cow will be reared and selected for breeding use when sibs are in first lactation. Female progeny from transferred embryos will be selected as donors after the second calving. Donor cows and service sires will be selected based on estimated lifetime performance. Performance of progeny of donor cows and breeding bulls from introduced embryos will be used to evaluates the effectiveness and feasibility of the breeding scheme.

INTRODUCTION

A major challenge of breeding superior dairy cattle for the future is the effective and optimal use of existing advanced reproduction methods in genetic improvement programs. Technical improvements in mbryo manipulation resulting in increased efficiency and reduced costs of obtaining embryos from elite cows are expected. This will permit economic production of genetically superior replacement females as well as bulls for use in artificial insemination. Techniques to produce large numbers of identical embryos (cloning) and non-destructive early embryo sexing, when completed, would be major breakthroughs allowing additional major increases in rate of genetic gain. The impact of the modern methods of reproductive manipulation on genetic improvement has not been adequately assessed theoretically or experimentally. The proposed research is designed to evaluate the impact of the new reproductive methods on breeding programs for dairy cattle.

Field data provide an excellent opportunity to evaluate and refine breeding programs currently in use. However, collection of specific data not routinely recorded, standardization of environmental conditions within herd, and imposition of experimental design constraints are very difficult and expensive. Once new methodologies are used widely, field data will provide the means of verifying their impact and refining their application. To attain wide use, initial experimental evidence justifying their use is required.

LITERATURE REVIEW AND EXPERIMENTAL DESIGN

The results of several studies collectively indicate the potential importance of maternal effects and have been presented by McAllister (1986) as part of this congress. However, they do not permit separation of pre-natal in-utero maternal effects from post-natal components. The transfer of genetically similar (full-sib or split) embryos from Holstein H and crossbred C line to recipients of H, Ayrshire based A and C lines of the current project (McAllister et al., 1978) permits separate estimation of the effects of genotypes of recipients, genotypes of embryos and their interactions. Should these effects be important, widespread use of embryo transfer technology would greatly magnify their impact.

Sib testing designs: The concept of using multiple ovulation and embryo transfer (MOET) for genetic improvement of dairy cattle was proposed by Nicholas and Smith (1983). Strictly additive inheritance with no maternal effects and no differential maternal and paternal inheritance is assumed. Increased annual rate of genetic improvement accrues from increasing selection intensity and halving generation interval while accepting potentially less accuracy of bull and cow evaluation. The use of dam and sire information for selecting heifers as donors (juvenile scheme) and the use of full and half sister as well as own performance for selection of donors after first lactation (adult scheme) are two alternatives presented. Bulls are selected based on sib and ancestor information. Implicit assumptions of the scheme are the selection of elite donor cows from industry at large to establish the program and continued ability to use the progeny testing scheme in industry to evaluate proven bulls. The nucleus population is then based on a very intensely selected base from the general population and can attain a substantial initial gain as well as a continued rate of genetic improvement superior to the national population. There appears to be great potential for the initiation of such programs. Some of the industry impact will come from multiple adoption of similar schemes and competing. Adequate nucleus population size, a minimum of 500, is essential. For a closed nucleus to perform successfully all progeny testing and selection internally after the foundaton population is established it would require over 1000 cows.

Everett (1984) examined the potential of embryo splitting and MOET. Unfortunately his consideration of clones implies that female members produce milk and that another embryo from the female clone could be transformed into a male. Hence his conclusions on accuracy apply to females from a clone but are not appropriate for bull selection without the ability to alter the sex of an embryo. Even full-sib information has a serious limitation on accuracy. Although the precision (r) of the genetic evaluation of the full-sib family increases rapidly as n, the size of the family, increases, ($r^2 = n/(n + 7)$), the accuracy of evaluating a member of the family is only $\sqrt{.5} = .71$ of this precision due to random segregation at meiosis and random union of gametes. Evaluating mating pairs for selection through progeny testing would lengthen generation interval rather than shorten it. Also, a large population would be required to test adequate numbers of pairs to permit intense selection.

Clones or split embryos have an important role to play in breeding programs. Sexing of one embryo, even if destructive, would identify the sex of remaining embryos of the clone. Evaluations for sex limited traits in that sex could become very precise, even for lowly heritable traits.

Production of males for evaluation on traits expressed in females can be in one of two ways. One would be to raise at least one male calf from each full sib family to semen producing age, store adequate semen to breed the required donors and dispose of the bull. When full and half sister information for a bull is available, discard semen from bulls of all but the elite full-sib families. This is the proposed approach. The other approach would be to make MOET matings to produce a bull one year later than those for general sib testing. The bull would then be of semen producing age at the time his full and half sisters have performance records. This would permit keeping selected bulls for much more extensive use than would be practical with semen storage. The choice relates mostly to practical alternatives for implementation. In any case a male from each full sib family would be raised to produce semen for breeding and used, subject to full and half sib performance.

Maternal inheritance and specific combining ability in Holsteins have been investigated (Lee and Henderson, 1969) using field data. Only mating designs with MOET permit accurate estimation. With MOET the change of service sires of donors either between flushes or between years would produce full-sib families within both maternal and paternal half-sib families. Even with only 1000 cow experimental population, this design would permit much more accurate estimates of these effects than in the past. Such basic questions are fundamental to the popular concepts of "cow family" effects (implying a stronger maternal than paternal pathways of genetic transmission) and "nicking" (the exceptional value of progeny from specific parental matings).

<u>Replacement Heifer Production</u>: Van Vleck (1981) has examined the value of an embryo transfer. Being able to ensure that a bull is obtained from truly elite cows for use in young sire sampling programs often justifies MOET. However, ensuring the dams of bulls are intensely selected on precise evaluations for the appropriate criteria is the most important aspect. The genetic value of producing heifer replacements through MOET is highly dependent on the difference in genetic merit between donor dam and the surrogate dam which would otherwise produce her own calf. The return from milk yield improvement appears to justify only a modest cost of an embryo over superior bull semen ($25 to 50 per embryo). Although not profitable for producing general heifer replacements at present, MOET will likely arrive at that point within ten years. At that time the knowledge base for effective use in breeder programs will be essential. The purpose of the proposed project is to provide that knowledge base ready for use when needed.

<u>Methods and traits for evaulation</u>: The mixed model multiple trait analysis of dairy production records (Schaeffer,1984) is an integral part of selecting cattle for long-term productive efficiency. Simultaneous sire and cow evaluation using records on all relatives is an integral part of MOET-based breeding programs. Hence development of genetic evaluation methodology is another aspect of this research. Research on lifetime profitability has been reviewed by Allaire and Thraen (1985). Burnside et al. (1984) reviewed the studies of relationships of type and first lactation production to longevity. The relationships of traits not previously studied, particularly those on heifers, to lifetime performance will be examined using accumulated experimental data. Results will be used to derive the selection criterion for estimated lifetime performance for use in the second phase of this project.

EXPERIMENT PLAN AND TIME SCALE

The project is planned in three phases linked with current research

(McAllister et al. 1978). The first (genetic parameter estimation) phase involves breedings from 1986 to 1990, births in 1987-1991, first lactation records in 1989-1993 and five lactation lifetime performance in 1993-1997. The second (sib-selection) phase involves breedings from 1990-1993, births in 1991-1994, first lactation records in 1993 to 1996 and five lactation lifetime performance in 1997-2000. New replacement research could be initiated by matings in 1994. The third (biotechnology phase) will be closely integrated with this project in 1986-1994.

The detailed recording of growth, reproduction, disease and lactation performance traits will be similar to that in current research. The data collection and processing system used for the current project will be upgraded to schedule the additional operations in the proposed project.

<u>Genetic Parameter Phase 1988-1990</u>: The purpose of this phase will be to study parameters related to embryo transfer, such as effects of surrogate dams (in-utero maternal effects), sex-linked and cytoplasmic inheritance. Full-sib and maternal half-sib families will be produced to permit evaluation of genetic parameters required for sib selection, utilized in the subsequent phase of the research, and for testing the routine use of new reproduction techniques in practical breeding.

In the first year, 1986, one third of the matings will be to the last of bull group from the current project and two thirds to introduced bulls. During the second year, 1987, all matings will be to introduced bulls and half the breedings will be by embryo transfer. In the third year, 1988, and following embryo transfer will be used for all matings, except the use of artificial insemination of those females failing to conceive after two or three embryo transfer attempts. Embryos transferred from 1987 through 1989 in the H line will be purchased from industry representing the best breeding stock available at reasonable cost. Embryos in the C line will be from matings of elite C line cows to superior Holstein bulls. Embryos will be randomized to H, A and C line recipients so that embryos of each genetic group are carried by all three genetic groups of recipients. In this scheme, differences between calf genetic groups within recipient genetic groups estimates autosomal genetic, sex-linked and cytoplasmic effects combined, free from in-utero maternal effects. Heterogeneity, if any, of these effects across recipient genetic groups estimates the interaction of embryo genetic group with recipient genetic group. Differences between recipient genetic groups within genetic group of embryo estimates in-utero maternal or recipient effects of genetic groups. Separation of autosomal genetic effects from the combination of sex-linked and cytoplasmic effects within genetic groups will be attempted by mating donor cows to different Holstein bulls at different embryo collections. Separation of nuclear sex-linked effects from cytoplasmic effects could only be accomplished by enucleating ova or embryos and inserting in similar and different cell membranes with associated cytoplasm. This is not practical at present in dairy cattle on the scale necessary for breeding studies. Live calf birth rate, calf survival, growth, reproduction, and lactation performance will be examined.

<u>Selection Phase 1991-1994</u>: This phase will develop and test a new breeding technique utilizing sib selection rather than selection based on progeny tests in genetic improvement. Theoretical calculations indicate the potential to increase substantially the rate of genetic gain through this method. Embryos

and semen for breeding will be collected from selected progeny produced in the previous phase. The selection criterion will be estimated lifetime performance. Effectiveness of the selection based on sibs and other relatives will be tested and biotechnology approaches will be integrated with conventional breeding techniques in a modern breeding plan.

In 1990, half the H line embryos will be purchased from industry and half will come from superior progeny of embryos used in 1987-88. From 1991 through 1993 all embryos will be from superior progeny of embryos used in 1988-91. Service sires will be changed between collections to generate maternal as well as paternal half sib families. At least one bull used for mating will be from superior breeding stock currently in use in the industry. Matings for subsequent research could begin in 1994 while multiple lactation data are accumulated on progeny of mating from this project through the year 2000. Matings from 1991-1993 permit accurate evaluation of cow family effects, non-additive genetic variance within and between superior lines of cattle and the adult sib selection program proposed by Nicholas and Smith (1983).

Biotechnology Phase 1986 - 1994: Throughout the above two phases and with increasing intensity as time progresses, a part of the animals in the herd will be utilized as donors of tissues for laboratory evaluations related to early assessment of performance potential, resistance to disease, and other potentially important parameters. Achievement of a detailed understanding of the cow's genetic makeup at the molecular level and of the associations between particular genes or segments of DNA and production characteristics will require extensive collaboration of quantitative geneticists with molecular biologists. It will also require large numbers of animals with detailed and accurate records to evaluate development and performance of modified genomes. The proposed research provides a unique opportunity to fully integrate research in dairy cattle breeding and biotechnology.

REFERENCES

ALLAIRE, F.R. and THRAEN, C.S. 1985. Prospectives for genetic improvement in the economic efficiency of dairy cattle. J. Dairy Sci. 68, 3110-3123.

BURNSIDE, E.F., McCLINTOCK, A.E. and HAMMOND, K. 1984. Type, production and longevity in dairy cattle: A review. Anim. Br. Abst. 52, 711-719.

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

LEE, A.J. and HENDERSON, C.R. 1969. Components of genetic variance in milk yield. J. Dairy Sci. 52, 780-789.

McALLISTER, A.J. 1986. Intensive milk production in temperate climates. Proc. 3rd World Congr. on Genet. Appl. to Livestock Prod. p

McALLISTER, A.J., BATRA, T.R., CHESNAIS, J.P., DARISSE, J.P.F., EMSLEY, J.A.B. LEE, A.J., NAGAI, J., ROY, G.L., VESELY, J.A. and WINTER, K.A. 1978. The National Cooperative Dairy Cattle Breeding Project. A.R.I. Technical Bulletin No. 1, Research Branch, Agriculture Canada, Ottawa, Ontario.

NICHOLAS, F.W. and SMITH, C. 1983. Increased rates of genetic change in dairy cattle by embryo transfer and splitting. Anim. Prod. 36, 341-353.

SCHAEFFER, L.R. 1984. Sire and cow evaluation under multiple trait models. J. Dairy Sci. 67, 1567-1580.

VAN VLECK, L.D. 1981. Potential genetic impact of artificial insemination, sex selection, embryo transfer, cloning and selfing in dairy cattle. In New Technologies in Animal Breeding (eds. B.G. Brakett, G.E. Seidel Jr. and S.M. Seidel) pp 221-242. Academic Press, London.