TOP REPRODUCTIVE PERFORMANCE OF DAIRY CATTLE IN TROPICAL CLIMATE WITH ASSISTED TECHNOLOGY

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ABSTRACT

For breeding scheme of dairy cattle under the hot and humid weather, selection on milk yield and quality associated with reproductive performance is essential, and therefore selected cows with reducing the age of first calving will become a heat-tolerance line in tropical climate. Assisted technology is used to ensure top reproductive performance of each herd under manageable feeding and housing system. Animal birth recording data of which accuracy is required depends on data uses in a system that measures data accuracy and identifies appropriate tools to assess is linked to data uses. To be economically efficient, dairy cattle must survive, reproduce, milk and grow in the environment determined by the ecological and socio-economic factors, and also by the feasibility of adopting advanced technologies. Major changes would be required, both at the farmer and industry levels, to improve management and technical services extended to farmers in order to make intensive systems based on profitable and rapid intensification of purebred. Under the market needs of milk quality uniformity, pure-breeding of high-yielding cows sired with imported semen is an assisted way to produce daughter lines with a higher productivity being easily adapted to local tropical climate. Age of first calving within 27 months was found in 41% of cows in 2001 and 63% in 2014, reducing first calving age did not have a significantly less fat% and protein% in milk along with less somatic cell counts and a higher daily milk yield under a breeding scheme for heat-tolerance and early mature dairy cattle in tropical Taiwan. For top reproductive performance of Ten Tons Cow, the cow is designated as milk yield of 305-2X-ME greater than 10,000 kg for hot and humid environment in Taiwan, and data were recorded from year 2001 to June of 2015. A total of 6,567 heads of Ten Tons Cow (top 3.6%) was recorded in a total of 182,870 cows from 361 herds. Based upon their maternal pedigree in upward three or more generations with their dam's milk performance data, a total of 381 Ten Tons cows (top 5.8%) from 2001 to 2015 was qualified on top reproductive performance. There was only one cow in 2002, but the number of qualified animals gradually increased from 11 cows in 2003 to 100 cows in 2015. Application of frozen semen from temperate USA and Canada in Ten Tons Cow population to select heifer in tropical Taiwan with assisted technology of birth recording system, milk analysis service, and genetic management, indicated that milk performance of purebred dairy cows in tropical climate could be improved in generations with a higher reproductive performance and less problems of summer infertility.

Keywords: Dairy cattle, Breeding, Milk quality.

INTRODUCTION

Hemme and Otto (2010) estimated that 12 to 14% of the world’s population (or 750 to 900 million people) live on dairy farms or within dairy farming households. Livestock provide over half the value of global agricultural output and one-third of this is in developing countries. Growth in agricultural production and productivity is then needed to raise rural incomes and to meet the food and raw material needs of the faster-growing urban populations (Moran, 2013). Because livestock products are more costly than other staple foods, their consumption levels are still low in developing countries, however, they are increasing as incomes rise. Milk is nature’s most complete food and dairy farming represents one of the fastest returns for livestock keepers in the developing world. Moran (2009) pointed out that the dairy industries of tropical Asia had failed to keep pace with the speed of dairy development in Western
countries over recent decades. Granted, the tropical environment is not ideal for dairy cows as high temperatures and humidity and seasonal rainfall reduce both the nutritive value of available forages and the level of cow comfort that is the production potential and welfare of the stock. In addition, many of the farmers, usually small holders with less than 10 milking cows, have not been able to develop the skills of efficient milk production. This has primarily been due to poor extension services more so than lack of technical knowledge on tropical dairy farming (Moran, 2013). A total of 10 key constraints were identified for small holder dairy farms in tropical Asia. Constraints of small holder dairy farms to profitable dairy farming can be categorized into institutional, governmental, socioeconomic, technical and post-farm marketing chain (Table 1).

**PROFITABLE DAIRY FARMING**

On any dairy farm, no matter its size or location, the dairy production technology can be broken down into nine key on-farm activities that can be considered as steps in the supply chain of profitable dairy farming (Moran 2009).

1. Soils and forage management: To optimize forage agronomy and fodder conservation.
2. Young stock management: To generate productive milking cows.
3. Nutrition and feeding management: To optimize cow performance through adequate supplies of feed nutrients.
4. Disease prevention and control: To overcome the limits imposed by microbial and invertebrate pests.
5. Reproductive management: To ensure herds can replace themselves in future generations.
6. Genetics: To maintain an acceptable rate of genetic improvement for each generation.
7. Environmental management: To limit the constraints of climate on stock performance.
8. Milk harvesting and hygiene: To maximize milk quality pre- and post-farm gate.
9. Adding value to milk: To improve unit returns for raw milk.

Within the technical research and development, Moran (2013) urged that the supply chain was only as strong as its weakest link. Each step in the supply chain of profitable dairy farming must be properly managed. Weakening any one link through poor decision-making and farming practices can have severe ramifications on overall farm performance and hence profits.

Many of the Southeast Asian dairy industries have recently established large-scale dairy feedlots to provide more milk and so reduced imports of dairy products (Moran and Doyle 2015). However, these countries all have government-driven development policies for small or medium-sized farms to continue to supply the bulk of locally produced milk. This means existing farms will need to be better managed. Given better farm management and strategic investments, the increased levels of milk produced on such farms should provide sufficient profits-incentives to upgrading current farm management practices. High performing genotype cows require excellent farm management to help them achieve their potential.

Optimized herd management is important for financially successful farming. Both, genetic and environmental improvement, require information collected on farms. The ability to collect data from the dairy farm and transmit to a centralized database under the national dairy herd improvement (DHI) program has resulted in significant advances in dairy herd management and genetic progress. Traditionally the information was collected on the farm once a month by sending human resources to the farm, and they either collect data from paper records and key those into a data collection software program, or extract data from the on farm herd management software and load these data into the data collection software program. Several sources of this type of data exist: milk recording, artificial insemination (AI) organizations, veterinarians, and on-farm computer software data. By collecting adequate cow fertility and health data for complex analysis of the reproductive status of individuals and herds, genetic evaluation of new functional fertility and health-related traits with higher accuracy for more profitable dairy farming could be possible. Due to the growth in the implementation of on farm technology such as robotic milking systems, heat detection systems, feeding systems, etc. the types of data and the frequency by which data become available on the farm has rapidly increased. This new data and higher volume of data from herd management assisted technology will further improve the reproductive performance of cows in tropical climate.

Over the past four years the animal data exchange working group of International Committee for Animal Recording (ICAR: www.icar.org) leading by Dr. Robert Fourdraine, has taken on the task of establishing a standardized data
interface that can be used by dairy industry partners to connect to on-farm systems extract data and transmit data to a centralized database. The standardized data interface is a two-way approach and will enhance value to the farmer and the providers of on-farm systems in addition to those providers with centralized databases. A test platform was established to allow providers of on-farm technology and milk recording organizations to test software. Two data flows have been developed one starting at a datacenter to on-farm equipment and the other from the on-farm system to a datacenter. Information has been identified to be beneficial under these two transmission scenarios.

**FERTILITY RECORDING**

The ICAR is a worldwide organization for the improvement of farm animal identification, recording and genetic evaluation. It develops rules, standards and guidelines for animal identification, recording and genetic evaluation. ICAR is registered as an international non-governmental and non-profit organization. Any new member organizations shall adopt and satisfy the ICAR Agreement on identification, recording and evaluation of farm animals within two years of taking up membership.

Records should be a true indication of the identity, sex, breed, ancestry and date of birth of the animal. Only information recorded in the manner and according to the standards of the Agreement shall be presented as the official record. The recorded animal must be identified in accordance with the animal identity regulations pertaining in the country where animal resides. Parentage, production traits and other characteristics including health traits shall be recorded in accordance with the Agreement. Recording standards for each trait are given in the ICAR rules (ICAR, 2014).

1. First insemination = first insemination to breed an heifer or to breed a cow after the end of each pregnancy.
2. Non-Return Rate (NRR) = percentage of females that are inseminated for the first time during a given period of time (such as a month) and have not been recorded as having returned for another service within a specified number of days (e.g. 24, 56, 90). Non-Return Rates (NRR) as a management tool for AI industry to characterize bull fertility and technician performance or to compare different semen treatments.

The day of insemination is Day 0. In a given herd, all females inseminated should be used for NRR calculation (without selection on reproductive parameters). Female breed(s) should be indicated. Calculation of a NRR (e.g. 56 day NRR) commonly excludes early returns according to the objective of the NRR (e.g. returns within 3 days after the insemination are excluded since it is considered usually as a problem due to females and not to the males). Thus, both limits of the considered interval should be indicated (e.g. 3-56 day NRR).

The number of first AI should be indicated for any NRR, since it is related to the precision of the estimation. For example, a NRR of 50% based on 100, 400 or 1600 AI will have a standard deviation of 5, 2.5 or 1.25 units of percentage.

The 60 to 90 day NRR has been a standard for AI organizations to work out breed receipts on a monthly rather than a daily basis. In that way the NRR of all the females bred in January is calculated at the end of March. The females bred on January first will have about 90 days in which to return. Those bred during the last days of January, however, would have had only about 60 days. Pay careful attention that the common phrases “18-24 day NRR” and “60 to 90 day NRR” get things confused. NRR of “18-24 day” addresses to the two limits of the interval, whereas “60 to 90 day” only addresses to the end of the interval which has the particularity to vary according to the month’s day of the insemination. The suggested expression of the NRR is as follow:

‘Given period’ (n=): ‘beginning of interval’ – ‘range of the end of interval’ day NRR =

e.g. For the year 1999 (n=15,332): 3-60 to 90 day NRR = 58.9%

**AGE AT FIRST CALVING**

The lifetime productivity of a cow is influenced by age at puberty, age at first calving and calving interval. One of the major problems on tropical small holder farms is the high calf mortality and the very high ages at first calving of
replacement heifers (Moran 2011). Pre-weaning calf mortality rates of 15 to 25% would be typical on many tropical dairy farms and can be as high as 50%; this contrasts to the 3 to 5% mortality rates on farms in temperate developed countries. Ages at first calving vary from 30 to 36 months on most tropical small holder dairy farms, compared the 24 to 30 month targets. These clearly indicate poor calf and heifer rearing practices. Many of these are due to poor stock welfare, such as inadequate housing and hygiene, which exaggerate the other shortfalls in feeding and disease management. Optimum age at first calving for total lifetime performance of dairy cattle was 22.5 to 23.5 months of age (Gill and Allaire 1976).

An earlier age at first calving can reduce rearing costs due to decreased feed, labor and building costs. An economic analysis showed that reducing age at first calving from 25 to 24 or 21 months decreased replacement costs by 4.3% or 18%, respectively (Tozer and Heinrichs 2001). Conversely increasing age at first calving to 29 months increased replacement costs by 14%. An increased age at first calving requires herds to keep more replacement heifers in order to maintain herd size, while reducing age at first calving allows surplus heifers to be sold, maximizing herd profitability in UK. The majority of UK dairy producers aim to start breeding Holstein-Friesian heifers from around 14 - 15 months of age, and thus the target age at first calving is generally 24 months on UK farms. Most countries, however, report a mean age at first calving of more than 24 months (Pirlo et al. 2000; Mayne et al. 2002; Hare et al. 2006) and only 14.6% of dairy operations surveyed in the US achieved an average age at first calving of ≤25 months (Losinger and Heinrichs 1997). The optimum performance in UK Holstein-Friesian cows over 5 years of working life was achieved with an average age of first calving 23 - 25 months, as these animals performed well in terms of both production and fertility and so survived longer in the herd. They were also more likely to achieve 3 lactations; this is crucial for profitability (Cooke et al. 2013). Recently, improving reproductive efficiency of heifers in UK also increases profitability through lower rearing costs with no adverse effect on productivity after calving.

The DHI has been one of the most important projects for dairy industry in Taiwan since 1978. It provides reports for dairy farmers to make cow selection and feeding management decisions. Reports of milk constituents, cows' performance information and farm management efficiency are published monthly for dairy farms (Chang et al. 2001). Chang et al. (2001) reported that a total of 217 dairy herds with 13,989 milking cows enrolled in the DHI program in 2000. The average herd size for milking cows was 64 heads per herd with average parities of 2.57; the average 305-2X-ME milk yield was 6,623 kg and the average daily milk yield was 21 kg. The average percentage of fat, protein and lactose in milk were 3.57, 3.11 and 4.55, respectively. The average somatic cell count in milk was 523x10E3/mL. Reproduction data of 9,712 cows in 1999 revealed that the interval after calving to first insemination was 117 days and the days open was 178 days.

Under a breeding scheme for heat-tolerance and early mature dairy cattle in tropical Taiwan, age of first calving within 27 months was found in 41% of cows in 2001 and 63% in 2014, reducing first calving age did not have a significantly less fat% and protein% in milk along with less somatic cell counts and a higher daily milk yield. Lactation records of Taiwan DHI cows from the national dairy database at www.angrin.tlri.gov.tw were used to determine calving ages across time. Data were used to study on trend in age at first calving from January of 2001 to December of 2014. In 4,685 cows calving in 2001, the percentage of cows showing first calving within 24, 27 or 30 months was 14%, 41% and 72%, respectively; these rates for 6,089 calving cows in 2004 were 15%, 42% and 70%, respectively for 6,893 calving cows in 2014 were 22%, 63% and 83% of cows (Figure 1). There were 1.5 times of increase on percentage of first calving within 24 months in last 14 years. In 2014, daily milk yield, milk fat (F), protein (P), lactose, somatic cell counts, urea nitrogen, citric acid and P/F ratio from 179,715 milk samples had yearly mean of 23.67Kg, 3.84%, 3.29%, 4.79%, 318x10E3/mL, 10.3mg/dL, 161mg/dL, and 0.89, respectively, compared with the average of 220,217 milk samples in 2002 having 21.77Kg daily milk yield, 3.73% fat, 3.22% protein, 0.89 of P/F ratio, 4.78% lactose and 350x10E3/mL cell counts in 2002. It indicated that cows reducing the age of first calving did not had a significantly less fat% and protein% in milk along with a less somatic cell counts and a higher daily milk yield. Reducing age at first calving to be 24 months old was observed and a line of heat-tolerance of dairy cattle was selected in Taiwan.

**MILK RECORDING**

Back to historic information, approximate years of first milk recording of dairy cattle in the early 10 countries in the world were 1883 in USA, 1895 in Denmark, 1897 in Germany and Hungary, 1898 in Finland, Norway and Sweden,
1899 in The Netherlands, 1900 in Austria and 1903 in Iceland and Scotland. In 1951, those of milk recording
countries in Europe worked together to form a small regionally bound organization as ICAR.

ICAR’s aim is to promote improvement of farm animal recording and evaluation through the formulation of
definitions and standards for the measurement of traits of economic importance. The present structure of ICAR as a
registered non-profit INGO provides for full participation of its members in developing guidelines and
recommendations on the basis of the sound scientific evidence. Guidelines represent a minimum of the requirements
set up to ensure a satisfactory degree of uniformity of recording among member countries, and a maximum
flexibility in the choice of methods (http://www.icar.org/pages/statutes.htm).

(1) Providing information and services which help member organizations to develop, operate and manage their
business;
(2) Providing information and services which promote benefits of recording and evaluation, thereby increasing the
demand for the services provided by ICAR member organizations;
(3) Providing guidelines and standards which facilitate the provision of services and the exchange of information
by member organizations both nationally and internationally; and
(4) Providing a body through which member organizations can work together to achieve shared objectives.

Taiwan joined ICAR in 2011 and the membership representative is Taiwan Livestock Research Institute (Figure 2). National milk recording data is in the web page of dairy cattle milk survey annually (http://survey-
icar.org/cow_survey). Milk yield per cow in 305 days in DHI farms of Taiwan was 7,728 Kg and was ranked on 21st position (Figure 3).

TOP REPRODUCTIVE PERFORMANCE OF COWS

Ten Tons Cow is designated as milk yield of 305-2X-ME greater than 10,000 kg for hot and humid environment in
Taiwan. For breeding scheme of dairy cattle, selection on milk yield and quality associated with reproductive
performance is essential to the hot and humid weather, and therefore selected cows will become a heat-tolerance line
for Southeast Asia. In 2001, there were 32 test-off Ten Tons Cow (0.1% to 28,381 cows for milk test), and then
number of cows up to 103 heads in 2002, 146 heads in 2003, 254 heads in 2004, and 312 heads (0.8% to 37,820
cows for milk test) in 2005. There was an increment of 9 times (312/32) for the number of ten tons cows for the past
five years. From 2001 to 2005, ages of test-off Ten Tons Cow were 52, 57, 50, 56, and 55 months old, respectively;
along with breeding value on milk yield (BVM) of +1113, +988, +1051, +960, +949 kg; and on fat yield (BVF) of
+41, +32, +40, +34, +35 kg, respectively. In 2006, there were 1,135 heads of Ten Tons Cow (3.4% to 33,064 cows
for milk test) with BVM of +894 kg and BVF of +33 kg. Those of Ten Tons Cow were raised in 150 farms (51.2%
to 293 testing farms) and among of 40 farms (40/293=13.7%) having more than 10 cows with a total of 797 heads
(70.22% to 1135 head). A total of 44 cows were selected with more than 12-tons milk yield with a mean of 44
months of age after 12 times of milk test in average, based upon number of milk test equivalent to their second
lactation, in 2006. Among of them, 8 out of 44 had more than three lactations. In conclusion, application of milk
yield and quality associated with reproductive performance would be feasible to improve herd performance in dairy
cattle.

Complex Vertebral Malformation, CVM, has three genotypes, normal (TV), carrier (CV) and defected (CVM).
CVM is a lethal genetic defect and refers to a combination of symptoms that include fused vertebrae, contracted
joints in the front and rear legs, reduced body size and etc. Major economic losses of CVM include stillbirth and
abortion. Malher et al. (2006) demonstrated that the relative risk of return-to-service was increased when the sire
was a CVM carrier and the dam was at risk of being a carrier, especially for late return (>25 days post-service).
With consideration of reducing number of CV carrier in high milk yield cow herds of Taiwan, a total of 1,756 cows from
17 herds were genotyped for CVM in 2008. The frequency of carrier CV cows was found to be 11.4% of population.
However, comparison analysis on 305-2X-ME milk yield of carrier (CV) and normal (TV) cows showed that there
were no significant difference in 305-2X-ME milk yield between CV (8,266 kg) and TV (8,403 kg) cows. No
difference was found on total solids, fat%, protein%, lactose%, milk citric acid, somatic cell counts, fat-protein ratio,
and urea nitrogen between them. To prevent those of CV carrier cows from being sired by CV carrier bull semen,
imported semen must be certified as normal genotype for use. The heifer born from carrier cow was genotyped for
genetic selection. In 2009, 15% of 574 Ten Tons Cows showed CV genotype. It indicated that the CV genotype cows had a higher milk yield but a less conception rate during summer season. Application of genomic selection combined with selection of milk yield and quality would be feasible to improve reproductive performance in Ten Tons Cows.

As mentioned above, for top reproductive performance of Ten Tons Cow, the cow is designated to have milk yield of 305-2X-ME greater than 10,000 kg for hot and humid environment in Taiwan, and data were recorded from year 2001 to June of 2015. A total of 6,567 heads of Ten Tons Cow (top 3.6%) was recorded in a total of 182,870 cows from 361 herds. Based upon their maternal pedigree in upward three or more generations with their dam’s milk performance data, a total of 381 Ten Tons cows (top 5.8%) from 2001 to 2015 was qualified on top reproductive performance (Table 2). In order to be a qualified on top reproductive performance cow, a Ten Tons Cow must have age at first calving within 27 months old, more than 3 lactations with a calving interval less than 365 days, no calving difficulty, and conceived within 90 days after calving. There was only one cow in 2002, but the number of qualified animals gradually increased from 11 cows in 2003 to 100 cows in 2015. To select cows with less problems of summer infertility, the mating month of first insemination after calving performed in April to June served as high-fertility indicator. Then, 228 out of 381 cows (59.8%) had summer pregnancy. In 2015 fertility data, a higher rate of 76% (76/100) was achieved in 29 farms. In conclusion, application of frozen semen from temperate USA and Canada in Ten Tons Cow population to select heifer in tropical Taiwan with assisted technology of birth recording system, milk analysis service, and genetic management, indicated that milk performance of purebred dairy cows in tropical climate could be improved in generations with a higher reproductive performance and less problems of summer infertility.

OUTREACH

Dairy cows with trait performance records and genotyping information in Taiwan DHI program have being promoted to improve production efficiency of dairy farms and to have next generation heifers from Ten Tons Cows, which had genes for adaptation to hot and high humidity weather. Thus, the tools and information have been developed to permit application of genomics into improving the health and performance of dairy animals. Clearly, low cost diagnostics should be based on its high economic value of pedigree cows in breeding stocks. ACTION was schemed to approach the goal on the genetic improvement of elite breeding stocks in private dairy farms of Taiwan with DNA-based screening for genetic defects and birth recording system as follows:

1. Aware status: to understand what I did and how to do it better.
2. Core facility: to have key tools for building data banks of individual animal.
3. Team ready: to agree the public-private partnership and for a better breeding program.
4. In-time service: to view results of screening for genetic defects in time.
5. Outreach system: to assist a new member what he/she can use.
6. Niche management: to evaluate the economic value and outcome of each allelic gene.

Elite breeding stocks in private dairy farms could be likely accelerated on their economic traits with assisted technology in reproductive performance recording and DNA-based screening for genetic defects in ACTION scheme.

REFERENCES


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<tr>
<th>Key activity</th>
<th>Key constraints for small holder dairy farms in tropical climate</th>
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<tbody>
<tr>
<td>1. Soils and forage management</td>
<td>1-1 Shortage of dry season forages</td>
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| 2. Young stock management         | 2-1 High calf mortality  
                                 | 2-2 Poor post weaning growth rates  
                                 | 2-3 High wastage rates (from birth to conceiving in 2nd lactation)                                                            |
| 3. Nutrition and feeding management | 3-1 Low quality of by-products and formulated concentrates  
                                 | 3-2 Poor performance of cows during early lactation (poor peak and daily milk yields, delayed cycling)  
                                 | 3-3 Cows (particularly high genetic merit cows) do not cycle for many weeks after calving  
                                 | 3-4 Seasonality of milk production  
                                 | 3-5 Little profits in milking cows                                                                                                  |
| 4. Disease prevention and management | 4-1 Problems with lameness  
                                 | 4-2 Problems with mastitis  
                                 | 4-3 High calf and heifer morbidity and mortality  
                                 | 4-4 General animal health problems                                                                                               |
| 5. Reproductive management        | 5-1 High age at first calving  
                                 | 5-2 Low 100 day in calf rate (pregnant within 100 days from calving) or high 200 not in calf rate (not pregnant within 200 days of calving)  
                                 | 5-3 High number of services per conception  
                                 | 5-4 Low% mature cows are milking                                                                                                  |
| 6. Genetics                       | 6-1 Poor milking cow quality  
                                 | 6-2 Most suitable genotype for the system                                                                                           |
| 7. Environmental management       | 7-1 High incidence of heat stress during the 24 h period  
                                 | 7-2 High incidence of animal health problems due to poor shed hygiene                                                             |
| 8. Milk harvesting management     | 8-1 Poor milk composition (fat and protein contents)                                                                                           |
| 9. Value adding milk              | --                                                                                                                                                |
| 10. Other on farm constraints      | 10-1 Poor profitability of dairy farming  
                                 | 10-2 Low capital resources for investing in farm infrastructure  
                                 | 10-3 Poor dairy farming skills  
                                 | 10-4 Underdeveloped entrepreneurial skills in dairy farmers                                                                         |
Table 2. The number of qualified Ten Tons Cow on top reproductive performance in Taiwan.

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Note: *Fertility 2015 data only included from January 1 to June 16, 2015.
Figure 1. Comparison on Frequency of Age at First Calving in Taiwan Cows (2014 vs. 2004)

Figure 2. ICAR has a world-wide membership network and a map of the ICAR member countries (in yellow).
Figure 3. Milk yield in 305 days, protein% and fat% of dairy cattle in ICAR member countries (adapted from ICAR dairy cattle milk survey)