Development of an Expert System

for the Evaluation of

Reproductive Performance and

Management of Virginia Dairy Farms

by

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(ABSTRACT)

An expert system for dairy herd reproductive management for microcomputer was developed using an expert system shell and Turbo Pascal. A dairy extension reproductive specialist provided information for the system and empirical support was provided by research. The expert system initially examines days open, days to first insemination, percent of possible estruses observed, and number of breedings per conception to determine whether a problem exists. Interpretations ranging from "excellent" to "severe" were established for each parameter. "Excellent" and "adequate" interpretations correspond to a 12 to 13 mo calving interval. The system then selects for evaluation one of three areas that influences days open; days to first insemination, efficiency of detection of estrus, or conception percentage. Once an area has been selected for further evaluation, the expert system utilizes information from the user and from DHIA reproductive management reports developed by the Dairy Records Processing Center in Raleigh, NC. The reproductive reports are captured in a computer file and read by the expert system to identify problems of conception categorized by production, parity, service, days in milk, breed, and service sire. In addition, questions are asked by the expert system to isolate problems in data accuracy, semen handling, AI technique, detection of estrus, signs of estrus, and other management areas. Recommendations and suggestions are given. The expert system was designed to be used by extension personnel who may not have extensive knowledge of computers or reproductive management. The compiled program runs on an

IBM compatible personal computer with 640K memory. Ten Virginia DHIA herds with conception problems were evaluated by the expert system and the extension specialist. Of 100 potential problem areas, the expert system and extension specialist identified 47, agreeing on 85% of them. Most discrepancies resulted from the expert applying a more restrictive standard when values were close to a preselected threshold.

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Introduction

Reproductive inefficiency is one of the most serious and frustrating problems of dairy farming. The problem is serious because of the economic losses associated with poor reproduction and frustrating because the problems are not always obvious and are often difficult to correct. A calving interval (CI) of 12 to 13 mo has been shown to be the most economically beneficial but is often difficult to obtain due to the biological and managerial problems associated with the reproductive cycle of the cow. The sum of the number of days open after calving, plus gestation length equals CI. From a management standpoint, the length of gestation cannot be altered; however, days open can be controlled by farm practices and management decisions. To obtain a 12 to 13 mo CI, the days open must be between 85 and 115. To correct problems with extended days open, three areas which influence days open must be evaluated. Days open is a function of when breeding begins after calving, how efficiently estrus is detected, and conception rate. A problem with any of these areas will result in extended days open. Each area should be analyzed when a problem with days open exists. The evaluation process should include an examination of herd records and management factors which influence these three areas.

Extension agents have long been the source of new information and technology and have solved many practical problems for dairy farmers. However, this has changed over the last few years for a variety of reasons. Because the number of people involved in production agriculture has been declining, the number of highly trained and specialized extension agents has also declined, thus many extension agents have become generalists instead of specialists. There is less money available for specialized training and traveling. Therefore, extension agents may have to deal with problems they know little about. Many times problems associated with dairy herd reproductive management represent one such area.

Recent technology in the area of computer programming, namely expert systems (ES), allows for simulating the thought process of human experts within a specific area of expertise. An ES for improving reproductive management captures the knowledge of the extension dairy reproductive specialist and allows that knowledge to be used by dairy farmers, extension agents, and herd consultants. From an initial evaluation of a herd summary form, a decision is made on which areas to evaluate. Average days open (DO), average days to first breeding (DFB), number of breedings per conception (CR), and percent of possible heats detected (ED) represent areas that are initially investigated. The area in need of the most attention is evaluated and suggestions for improvement are given. The goal of this project is to investigate the factors which influence DFB, CR, and ED and develop an expert system that will help dairy farmers reduce DO and shorten CI.

Review of Literature

Expert Systems

Rolston (61) defined ES as computer programs which capture the basic knowledge that allows humans to act as experts when dealing with complicated problems within a specific domain, or area of knowledge. The most important difference between an ES and other computer programs is the ability of the ES to evaluate and solve problems much like a human. An ES uses extensive specific knowledge, i.e data and facts, from a specific area and then applies search techniques to locate rules similar to those used by humans to solve the problem. Much of the human decision process is heuristic, which implies the understanding of relationships between data and facts. This relationship is also known as knowledge and common sense. An ES is able to support heuristics, thus allowing for non-algorithmic reasoning, which is not as easily available in other computer programs. Expert Systems also have the ability to use data to infer new knowledge. Unlike other computer programs, ES can utilize symbolic processing which eliminates the need for complex computer languages and allows people with limited computer skills to develop an ES. An ES can also explain the reasoning process which led to the solultion of the problem. This explanation can serve as a teaching tool for the ES user.

There are several reasons why ES are being developed. Many times human experts are not available when and where they are needed. There are not many experts within a specific area. By capturing the expert's knowledge in an ES, more people can benefit and the knowledge and experience of the expert will not perish. An ES is also more consistent in its problem solving ability than a human, because the same problem is solved the same way every time. However, this can also be a disadvantage. Humans can take into account human conditions which a computer can not. For example, a computer cannot look into someone's eyes and determine whether or not the truth is being told. Human expertise is also expensive and an ES should be able to reduce the cost of having human expertise to solve problems. However, the cost of developing an ES must be weighed against potential benefits. A problem with the knowledge within the ES is that it may change as the knowledge base changes. Data and facts must constantly be updated so that the ES remains consistent with human expertise. The most difficult problem associated with ES development is documenting and transferring human expertise into the ES. A human expert must exist in the specific area of interest. The expert must be willing and able to articulate the expertise to the knowledge engineer, who then transfers the knowledge into the ES. Although the potential uses for ES are limitless, the most popular area of ES use is the area of diagnostics.

An ES consists of three parts. The knowledge base contains data, facts, rules and relationships. An inference engine uses the knowlege base to solve problems and then gathers and displays information through the third part of the ES, the user interface. The inference engine can use several problem solving techniques which are similar to a human's ability and reasoning. Backward chaining is the most common method used by ES. The ES begins with a goal and tries to prove the goal to be true by working backward through the knowledge base. Forward chaining refers to the ES working forward through the knowledge base to gather data to prove a goal is true. Most ES developers use ES shell programs which contain all three parts and are capable of both forward and backward chaining. The developer writes the knowledge base within the shell program. The shell provides the inference engine and user interface. This process reduces the need for complex computer programming languages. The eventual user of the ES must be known to the developer so that an appropriate level of knowledge is written into the ES. An effort must be made to make the ES reasonably easy to use.

Expert Systems were first developed in the 1970's and have not been used in dairy herd management extensively. Smith (76) and Spahr et al. (79) reviewed potential ES applications in dairy management and indicated that research is going on in this area. They pointed out several problems associated with developing ES for dairy management. Many times computer programmers develop an ES without the assistance of a dairy management expert, which sometimes makes their program difficult to understand and use. The goals and purpose of the ES are not well defined. Too large a problem is often defined and may not be suitable for an ES. The problem may have to be divided into smaller knowledge bases and the technique of knowledge base chaining, or connecting, used. An ES is only a tool for problem solving and is only as good as the information which is in the knowledge base and the information which the user provides.

Economics of Reproduction

Before developing an ES in reproductive management, it is important to understand the importance of dairy herd reproductive efficiency. Pelissier (59) concluded that reproductive inefficiency is one of the most serious problems facing dairy farmers. He suggested that breeding problems reduce gross income because milk production is reduced and fewer calves are born. Furthermore, production costs increase due to higher replacement, veterinary and breeding expenses. The combination of lower milk production and higher production costs reduces net income. The estimated losses from these factors totaled $116.25 per cow in 1981. Unrealized milk sales accounted for 53% of the total while the additional cost of herd replacements and loss of calves made up 37%. The remaining 10% was due to increased breeding and veterinary costs. In addition, the negative influence of poor reproduction on genetic progress must be considered, but it is difficult to assign a cost to this loss. Breeding problems decrease the number, and genetic potential, of calves that are born, which is due to reduced use of high PTA bulls which are often more expensive. High PTA bulls are avoided because of the fear of repeat services which may be needed. In 1975, Lineweaver (43) suggested that in Virginia the average yearly loss per cow due to poor reproduction was nearly $92, as indicated by a 410 d CI for the state. Britt (7) concluded that the profit of dairy herds was adversely affected by poor reproductive performance, which in turn affected milk produced per cow per day, number of replacements produced and rates of voluntary and involuntary culling.

Work of Louca and Legates (44) provides the foundation on which much of the research in the area of reproduction and economics is based. They concluded that from an economic standpoint, milk yield per unit of time a cow is in the herd is more important than individual lactation performance. They performed two separate studies. The first study examined total production of individual cows to the end of the lactation completed nearest to 48 mo after first calving. This was to eliminate the bias of having older, selected cows in the data. Regression analyses within herd and year of first calving, holding constant age at calving, total days dry and total days in milk, revealed a quadratic relationship between DO and production. An average decrease of 1.31 to 3.49 kg of milk production and .072 to .152 kg of fat production occurred with each additional day open. An upward trend in total milk yield occurred at 700 total DO, which suggested that the 44 cows that were beyond 700 DO were not culled because their production was high enough to compensate for poor reproduction. The second study utilized shorter production intervals, 1580 first and second, 1050 second and third and 700 third and fourth lactation pairs. Yields per day for the interval from 210 d after calving to 305 d of the next lactation were used as dependent variables in the model. The exclusion of the first 210 d of production accurately reflected the effect of days open rather than the inclusion of total production. It was concluded that pregnancy did not affect milk yield until 5 mo after conception. Therefore, the first 210 d of yield was not influenced by pregnancy. Using a similar regression model as in the first study, they found that each DO was not uniformly expensive for all lactations. An increase of 1.16 kg of milk and .071 kg of fat for each additional DO was calculated for first lactation. Second and third lactations declined by 3.58 and 3.68 kg of milk, respectively. The difference between first and later lactations was attributed to the greater persistency of first lactation. Each additional DO in first lactation had less effect than a DO in second or greater lactations. From an economic standpoint, they considered a reduced calving rate and loss in milk yield and determined that a net decrease in income for each additional DO would be between $0.25 and $0.75 based on a return of $0.05 to $0.12 per kg of milk and $25.00 to $100.00 per calf. From this research, they suggested a CI of 13 months for first lactation and 12 for second and beyond.

Schmidt (67) determined the effect of calving intervals on income over feed cost (IOFC) and variable costs using a microcomputer spreadsheet. Various milk yields and prices, feed prices, and culling strategies were used. Income over feed costs for 12 and 13 mo CI were virtually the same across three different production levels. However, 14 and 15 mo CI had lower IOFC. When the culling decision was based on a cow age of 78 mo, and milk yield was 10,000 kg/yr, the decrease of IOFC per day was $0.02, $0.59 and $0.56 for increasing CI of 13, 14 and 15 mo. When culling was on the basis of lactations, extending the CI increased IOFC because the increased milk yield from the longer CI was greater than the increased variable and maintenance costs used in the analysis. The greatest increase in IOFC occurred between 12 and 13 mo. However, in the model, culling took place at the end of the lactation, where in practice, culling is a continuous process. The difference in IOFC between the two culling practices indicated the importance of milk yield per unit of time the cow is in the milking herd. High milk price and low feed cost had the greatest effect on IOFC. A 12 to 13 mo CI appeared to be the best strategy under the economic considerations in this study.

Holmann et al. (38) found little effect on IOFC in the short run for modest changes in CI. Depending on the level of milk production used in their budgets, a gain of $0.21 to $0.41 in IOFC per day was calculated for each day open between a 12 and 13 mo CI. A decrease of between $0.04 and $0.23 per day was found for increasing to a 15 mo CI. A 13 mo CI appeared to be optimal. However, they suggested that there may be an incentive to milk cows in late lactation as long as the difference in IOFC per day compared to the dry period exceeds the cost of milking. This study only examined short run situations and did not take into account culling and reduced replacements from extended DO. Olds et al. (55) concluded that milk yield per day of CI decreased as DO increased. More time was spent at the lower end of the lactation curve. Days open influenced days in milk, days dry and the rate of decline in production after 120 days of lactation. Increased persistency associated with additional DO accounted for higher 305 d production. For first lactation, each additional DO between 40 and 140 d postpartum resulted in $0.71 less IOFC per day, while for second or greater the loss was $1.18. Although the dollar values observed by Louca and Legates (44) were different than those of (38) and (55), all of the research indicated that extended DO affected second or greater lactations more than first lactations.

Rounsaville et al. (64) simulated 21 herds of 65 cows and quantified changes in DO, DFB, CI, number of annual services, and annual culling rates over a 10 yr period due to three levels of ED, CR and culling policies. Estrus detection percentages of 35, 55 and 75%, CR of 42, 50 and 58% and culling after three, four, or five services were compared in all possible combinations. Minimum DFB was 60 d. Differences in ED appeared to be the primary factor affecting DFB, DO and CI. Changes in CR and culling policy also significantly influenced DO, CI and culling. A DFB average of 90 d and a DO of 120 d was found when ED was 55%, CR was 50% and culling was after four services. Increasing ED to 75% decreased DO to 104 d while decreasing ED to 35% increased DO to 140 d. The economic consequences of changing the level of each variable in the simulation were also studied. A change in culling policy required no extra expense to the farmer. Changes in ED and CR may require significant expenditures in labor and materials. For example, labor is needed to implement ED programs or AI re-training may be necessary to improve CR. In their economic analysis, which does not include differences in milk yield due to increased DO or the implications of poor reproduction on genetic progress, changes in CR and culling policies were most economically beneficial to the farmer. A change from poor to average CR resulted in a savings of $596.00 per herd annually due to decreased number of services and herd replacements needed. According to their analysis, changes in ED were more costly to implement and not economically beneficial, a fact which may be useful in the design of an ES. Their cost analysis was not complete enough to make general recommendations regarding appropriate levels of DO, ED and CR.

Oltenacu et al. (57) simulated the effects on profit from an improvement in ED and CR. When CR was constant at 50%, an improvement of ED rate from 35 to 55% resulted in an additional return of $60.00 per cow annually. When the ED rate improved from 55 to 75% and CR was 58%, an increase of $8.00 in additional return was found. Their study indicated that a point of diminishing returns is reached beyond an ED rate of 60% and a CR of 50%. However, in this simulation, the postpartum delay to first breeding was 60 d for all cows, which may not represent actual farm practices. Olds (52) in a review of management techniques for shortening CI, concluded that a 12 to 13 mo CI should be the goal for dairy farmers.

General Factors Affecting Conception

Conception rates of dairy cattle can be affected by many factors. There are several main areas in which conception and conception problems can be classified. DeKruif (16) considered the bull, the method of insemination, the cow, conditions of herd management, and chance as the main areas of interest when discussing CR. The bull effects CR through artificial insemination (AI) and natural service. The fertility and health of natural service bulls needs to be considered in appropriate situations. Artificial Insemination organizations should provide high quality frozen semen that has ability to fertilize cows so that the bull's affect on CR will be limited. Insemination techniques, including timing of AI and site of semen deposition, also affect CR. The cow's effect on CR includes age, milk production and disease. Conditions of herd management refer to climate, season, size of herds and housing. Furthermore, the effect of management decisions and practices such as choice of bull, animal hygiene, interval between calving and first breeding, accuracy of estrus detection, nutrition and culling all affect CR.

Hillers et al. (36) and Ron et al. (63) concluded that accuracy of estrus detection, proper inseminating techniques and good herd health can directly influence CR. Factors beyond the immediate scope of reproductive management, such as milk yield, age and season, can be controlled if their relationship to reproduction is understood. For example, efforts to cool cows during warm months is beneficial to reproduction. A study in West Virginia (14) found that individual cow reproductive performance was affected by season of calving, production, age and reproductive disorders. Research by Shanks et al. (73) concluded that season, parity, uterine involution, ovarian condition, retained placenta, dystocia, embryonic death, reproductive treatment and number of services explained 71% of the variation in CR. Call and Stevenson (11) felt that the key to improving herd reproduction begins with the individual cow due to the wide difference in fertilization and calving rates among cows.

Timing of Insemination

Once a cow has been observed in estrus, only a short period of time is available for insemination and conception to take place. On day 17 of the estrous cycle, progesterone from the corpus luteum (CL) is declining and estrogen from the maturing follicles is increasing. This increase in estrogen causes a surge of luteinizing hormone followed by ovulation 19 to 33 h later. Duration of the LH surge is 4 to 10 h and corresponds with the beginning of standing estrus. Unlike most farm animals, ovulation occurs after estrus has ended. After ovulation, the ovum moves down the oviduct and for 12 to 24 h is capable of being fertilized (21,77). Not only is the cow's physiology important to the timing of insemination and conception, but sperm and sperm transport plays a key role. Hawk (35) indicated that sperm is viable in the cow's reproductive tract for up to 48 h, with maximum concentration of sperm occurring in the oviduct, the site of fertilization, 8 to 12 h after insemination. For capacitation, which is required for fertilization, sperm have to present in the reproductive tract for 6 to 8 h. The sperm and ovum should meet at an optimum time so that there is a higher probability that conception will occur. Because the ovum has a shorter fertile life than sperm, knowing when the cow ovulates would help determine a precise time of insemination. The only way to know when a cow is going to ovulate is to observe her in estrus unless breeding is preset after some type of hormonal treatment is administered. Early work in this area (2) demonstrated that CR was lowest when insemination occurred less than 3 h or more than 20 h after estrus. From this information, Trimberger (88) developed the AM/PM rule, whereby cows observed in estrus in the morning were inseminated the same evening and those in estrus in the evening were serviced the following morning. Most researchers generally agree with this guideline. However, variation exists because of the variable interval between the onset of estrus and its detection, which is a direct function of frequency and efficiency of estrus observation, cow variation and other environmental factors. Reimers et al. (60) utilized the AM/PM guideline and found CR of 52.2% for evening and 47.1% for morning inseminations, which were statistically different. Foote (26) used fresh semen and AI technicians to compare 150 d percent non return rates among different times of insemination after detection of estrus. He found that CR was lower for inseminations taking place more than 24 h after detection of estrus. Work in Kansas (82) involving 732 cows inseminated the same morning, the next afternoon, or the morning following detection of estrus measured a CR of 53, 47, and 47%. Cows inseminated the same afternoon of estrus had a CR of 26% which indicates that cows which came into estrus during the afternoon were being inseminated near the beginning of estrus, whereas other cows were being inseminated at later times relative to the onset of estrus. Gwazdauskas and co-workers have investigated this area extensively (29,31,90). Their work indicates there is no difference in CR in cattle when insemination takes place when first observed in estrus or 12 h later if estrus checks are performed twice daily. Conception rate ranged from 42.7 to 57.3% for varying times of insemination after detection. Estrous behavior 12 h after being detected was related to CR. Cows in standing estrus had a higher CR than those not standing, 57.2 to 48.1%. Olds (53) concluded that maximum CR occurs when insemination takes place 20 h after the onset of estrus and that knowing when estrus begins is the key to maximizing CR. Because the detection of estrus is often difficult, the AM/PM guideline should be followed by most farms.

Nebel et al. (49) suggested that milk progesterone testing can be used to confirm estrus and prevent insemination of a cow not in estrus. High progesterone levels indicate no estrus and cows should not be inseminated. Therefore, CR would improve because cows not in estrus would not be insemininated.

Control of the Estrous Cycle

Because of the difficulty of detecting estrus, which is important in determining when ovulation will take place, work has been done to determine if the estrous cycle could be controlled in such manner that a scheduled insemination could improve CR. Control of the estrous cycle means controlling the life span of the progesterone producing CL (8). The CL controls the estrous cycle by producing progesterone from day 5 to 16. Progesterone is the dominate hormone until prostaglandinF2α (PG) from the uterus stimulates the regression of the CL. This regression allows a follicle to develop, produce estrogen, and ovulate. After ovulation a CL forms by day five and the cycle begins again unless conception occurs. A single, timed breeding resulting in maximum fertility is the goal of ovulation control (42).

One of the more popular methods of controlling ovulation is the use of PG. However, other methods have been researched (42). Many methods are complicated and may not be practical on dairy farms. Treatment with PG will affect estrus and methods used for detection of estrus. Simmons et al. (74) found that 56.9% cows treated with PG were observed in estrus within 5 d of treatment, which they felt was low when compared to 66% from other research. They felt that this difference was related to differences in efficiency of detection of estrus between experiments. Lauderdale (41) reported that adminstration of PG on days 2 to 5 of the estrous cycle, estrus occured an average of 17 d later, which indicated that administration of Pg had no effect. Administration between days 6 to 16 produced estrus 2 to 4 d later. For PG to be effective, a CL must be present. Insemination between 72 and 96 h post PG treatment would appear to be optimum. Frequently a routine of two inseminations is implemented so that viable sperm can be available for longer periods of time.

Sequin et al. (72) found that 72 cows bred at 72 and 96 h post PG treatment had a CR of 59% while 72 cows bred on signs of estrus had a CR of 40%. He concluded that double appointment breeding may yield higher CR than single appointment, but a single insemination between 72 and 96 h should be adequate. A review by Lauderdale (41) indicated that CR of controls, PG bred on estrus and PG bred by appointment at 72 and 90 h were 58, 57 and 58% respectively. Simmons et al. (74) classified 22 cows as non-responders (no observed heat) to PG treatment at 60 d postpartum. Three of the 22 cows conceived to an insemination 75 h after treatment. However, six non- responders had no palpable CL on day 60 and five cows had progesterone levels below 1.0 ng/ml. This indicates the importance of using PG only on cows having a mature CL. Gwazdauskas et al. (31) found a CR of 20.7% on 87 PG treated cows that were not seen in estrus by 60 d postpartum or failed to return to estrus by 90 d and were inseminated by appointment at 80 h. Conception rate was 49.5% for 99 cows treated with PG and inseminated on signs of estrus. Whether or not cows had a CL at time of injection is not stated. The current recommendation for scheduled breeding is one insemination at 80 h post treatment. If the cow is seen in estrus before or after 80 h, the cow should be inseminated or re-inseminated (75).

Cow Effects on Conception Rate

After calving, the cow needs time to return to reproductive soundness and cyclicity. In addition, high producing cows are under stress of milk production. Both of these factors may lower CR. However, under good herd management, their effect can be reduced. Britt (6), in a review of early postpartum breeding research, found that the CR for cows bred less than 25 d postpartum was 25% and increased to 60% at 60 d and then stabilized. Hillers et al. (36) examined CR in four large commercial dairies in Washington and found a CR of 32% for 36 cows inseminated less than 50 d postpartum. Of 578 cows bred between 50 to 59 d, 49% conceived, and of 829 cows bred between 60 and 69 d, 53% conceived. Reasons for this lower CR at earlier breeding are varied, but uterine involution is known to be important. Fonseca et al. (24) found that the average days for uterine involution for 96 cows was 23.8 d, with a maximum of 70 d. Factors which affected uterine involution included milk yield, age, and abnormalities at parturition and postpartum. Abnormalities at parturition and postpartum increased days to uterine involution by 8.6 and 4.9 d, respectively. Days to uterine involution declined as 70 d milk yield increased up to 1400 kg, but then increased with higher production. Only Jersey data were presented, although the author stated that results for Holsteins in the study were similar. Days to uterine involution increased with cow age. This study utilized university herds with cows that were not culled as selectively for low production as commercial herds. Studies involving commercial herds maybe a more accurate indicator of the effects of age and milk yield on CR, especially from a practical standpoint. Older cows maybe more susceptible to effects of higher production and also require more time to recover from calving abnormalities.

Oltenacu et al. (56) examined 492 cows at 8 to 21 d postpartum and again 2 wk later. Cervix diameter was divided into small (40 mm), medium (40 to 55 mm) and large (55 mm) for first lactation and added 5 mm for second or greater lactations. Cervical involution was adversely affected by increased cow age and abnormal uterine discharges. First service CR was 67, 52 and 46% for each group. Days open and first detected estrus were adversely affected by calving abnormalities. A total of 14.1% of all calvings were abnormal and 38% had an abnormal discharge. They concluded that the optimum time to determine cervical size is at 3 wk postpartum when the difference between normal and abnormal diameter is greatest. Thompson et al (87) found that on California dairies the incidence of dystocia and calf mortality decreased with parity, while problems such as milk fever and retained placenta increased with parity. Erb and Martin (20) concluded that cows from 2 to 4 yr of age had more dystocia than older cows, while 7 to 10 yr old cows had more retained placentas and metritis.

Taylor and co-workers (85) reviewed DHI records for 97,245 cows in 1075 herds in New York. They found that CR increased with herd milk production, which they attributed to higher levels of management. Conception rate decreased with both increased cow age and increased number of older cows in the herd. Furthermore, CR for inseminations one to five were 55.5, 52.5, 51.3, 49.7

and 48.1%. Laban et al. (40) utilized 201 dairies in California in their research. They found that for an individual cow, high yield and associated factors, including age, had a small antagonistic association with CR. Number of breedings for conception increased .014 for each increase of 100 kg in 180 d yield of FCM. However, the number of breedings changed little as herd yield increased, which was attributed to more competent levels of management in higher producing herds. The highest producing herds averaged one estrous period (21d) shorter DO than lower producing herds, which suggests better heat detection. Olds et al. (54) used 120 d cumulative milk yields in their research for two reasons. The earliest effect of gestation on milk yield is at 95 d of gestation. They also suggested that there is disagreement among researchers on whether higher 305 d milk yields increase DO or more DO increase 305 d milk yields. From 26,805 Holstein records they developed a partial regression coefficient which indicated about .014 more services for every additional 100 kg in 120 d milk yields. The correlation coefficient between 305 d milk and number of services was .165. When this correlation was independent of DO, the correlation was .03 which indicates that 305 d milk and services per conception are unrelated after being mediated through DO. Therefore, they concluded that 305 d production does not affect services per conception directly. Services per conception and DO are correlated at .66. The small effect of 120 d milk on services per conception is related to DO, which in turn affects 305 d production. Hamudikuwanda (34) found a .009 increase in services per conception for each 100 kg increase in cumulative milk yields at 60 d indicating a slight linear antagonistic relationship. However, Spalding (78), utilizing 305 d milk records from 9750 Holsteins, discovered that CR declined significantly with increased production when age, herd size and farm management factors were not allowed to vary. First service CR declined by 20.7 percentage units for cows producing greater than 908 kg above herdmates compared to cows producing more than 908 kg below herdmates. This trend continued for the first three services. Average first service CR was 50%. Conception rate also declined for cows greater than 4 yr of age. Faust et al. (22) used 305 d ME records and three production categories, less than 7250 kg (1174 cows), 7250 to 9750 kg (1978) and more than 9750 kg (241) and found that CR was 56.5. 37.8 and 17.4%, respectively. Hillers et al. (36) concluded that CR was not severely influenced by production, noting only a slight difference in lactation production groups and first service CR, with higher producers having slightly lower CR. He concluded that it is difficult to separate confounding affects of management with possible biological effects. Conception rates declined with lactation number, 54, 55, 48 and 44% for one, two, three, and greater than three lactations. Shanks et al. (73) concluded that cows giving more milk had a higher CR because they are healthier than less fertile cows. Ron et al. (63) showed that heifers had a CR 20 percentage units higher than cows, indicating that milk production does affect CR. Milk yield, calving problems, cow age and service number effect CR, but management can minimize adverse effects of these factors.

Cow Health

Cow health and body condition affect CR by altering biological processes important to CR. Stevenson and Call (81), and Erb and Grohn (19) reviewed research associated with reproductive and metabolic disorders in the periparturient dairy cow. Several disorders were reviewed. The incidence of dystocia in eight studies comprising 218 herds averaged 5.8%, with a range of 0.9 to 13.7%. Retained placentas had an average incidence rate of 9.4%, with a range of 2.0 to 17.8%. The incidence of milk fever ranged from 1.2 to 14.1%, with most herds surveyed reporting below 7%. A range of 1.1 to 9.2% was reported for ketosis. One of the problems associated with research concerning incidence rates of certain disorders is the definition used to describe the disorder. All of the disorders have been shown to lower reproductive efficiency.

The importance and problems involved with herd reproductive health programs were outlined by Drost (17,18) and Youngquist and Bierschwal (91). Reproductive health considers all factors which may affect reproduction, including disease, metabolic disorders and difficulties associated with calving. Vaccination programs for brucellosis, leptospirosis and other diseases should be a part of a health program and have been shown to play a part in improving herd reproductive performance (51). Regular herd visits by a veterinarian have been found to be the most consistent factor influencing herd reproductive performance (14). Drost (18) suggested that three different groups of cows should be examined at regular herd visits. Group 1 should consist of cows 30 d post partum so uterine involution and ovarian activity can be checked. Group 2 should be cows ready to be checked for pregnancy (40 d after service). Group 3, the most important group, includes cows with any abnormality such as retained placenta, irregular cycle or abortion. This systematic approach to reproductive health allows for early recognition and disposition of breeding problems. Galton et al. (27) investigated the effects of a herd health program on reproduction. Cows in a herd health program which included routine veterinary visits had a CR of 58% compared to 41% for the control. Days open were 99 and 140, respectively. Herd health cows also produced 255 kg more FCM per lactation. Cows in the herd health program had a net return of $0.16 more per cow per experimental day than controls. Zweigbaum et al. (93) found that the use of veterinarian for comprehensive reproductive health program increased net cash income by $152 per cow annually.

Cows in early lactation cannot increase dietary intake sufficiently to keep up with nutritional demands of increasing milk production. Therefore, cows must mobilize body reserves to compensate for dietary deficiencies. This condition is referred to as negative energy balance and will affect the body reserves of the cow (10). This change in body condition has been related to reproductive performance. Ferguson (23) reviewed research associated with body condition scoring and reproduction. Utilizing the body condition scoring system developed by Wildman et al. (89), changes in body condition scores affected CR. Cows were scored on a scale of 1 to 5, with 1 being extremely thin and 5 being extremely fat. No change in body condition score from calving to breeding resulted in highest CR at 50%. A decrease of 1 or 2 had a CR of 34 and 21%, respectively. The effects of body condition score changes can be reduced by proper nutrition, especially during late lactation and the dry period.

Environmental Factors

Environmental effects can be divided into the physical environment including climate, shelter and space, and the biological environment encompassing food and water, disease prevalence, and social and human interactions. Dairy farmers have some control over the biological environment. For example, nutritionists can balance rations to provide proper nutrition. The physical environment, specifically climate, is difficult to control with reasonable cost and can have a detrimental effect on CR. The movement of the dairy industry into the warmer climates of California, Arizona and Florida makes unnecessary the extensive housing utilized in the cooler northern states. However, severe and stressful environmental conditions exist during summer months. Gwazdauskas et al. (32), in a review of literature, reported that between 1929 and 1956, CR was lowest in summer months and highest in the spring. Furthermore, Stott (84) attributed seasonal depressions of fertility to the female more than the male. High temperatures may act directly on the developing embryo or may cause endocrine imbalance in the cow. Thatcher et al. (86) reviewed possible physiological causes and effects of thermal stress and called the complex process "the infertility heat stress syndrome."

The University of Florida has researched the area of thermal stress extensively. An early study (30) indicated that uterine temperatures and average ambient temperature on the day of insemination were inversely related to fertility. Mean uterine temperatures at insemination and 14 h later were 38.4 and 38.6 C. Partial regression coefficients indicated that every .5 C above mean uterine temperatures reduced CR by 12.8 and 6.9% units. Average daily temperature for the 1 yr study was 18.3 C and was more important than humidity measurements. In addition, temperature the day after insemination was found to have more influence on CR than temperature on the day of insemination. However, no CR was reported. Further work at Florida (32) found an overall CR of 37.9% on 5062 services over 11 yr. The five most important climatic measurements in the model were maximum temperature the day after insemination, rainfall on day of insemination, minimum temperature the day of insemination, solar radiation on the day of insemination and minimum temperature the day after insemination. Warm months had a CR of 33.7%, while winter months were 40.1%. Average maximum daily temperature was 24.4C. Ron et al. (63) in Israel found that CR was 51.0% in January and 26.0% in August and concluded that no other factor affected CR more than month of insemination. However, month of insemination had little effect on CR of heifers, which would suggest that milk production exacerbates thermal stress. Stevenson et al. (83) in Kansas concluded that when ambient temperature was between 1 and 32C, CR was above 40%. Morning inseminations had an 11% higher CR than evening inseminations, which may be related to temperature. Gwazdauskas et al. (31) determined in a university herd that a maximum CR of 55% occurred when the ambient temperature the day after insemination was 10C. A rapid decline in CR occurred at less than 5 and more than 15C. Research on the effects of temperature on CR in mild climates showed temperatures do not affect CR as severely. Hillers et al. (36) in Washington State and Matsoukas and Fairchild (46) in New Hampshire found no monthly or seasonal effect on CR.

There are several methods available for reducing thermal stress. The simplest method of control is to provide shade. Roman-Ponce et al. (62) using a simple shade structure in Florida found a CR of 44.4% for cows with available shade and 25.3% for cows without shade under the same management conditions, which indicates that even the simplest system of relief is better than none. In a review of research related to environmental effects, Gwazdauskas (28) concluded that the optimum maximum temperature for conception is between 10 and 23 C. Different management and housing methods can be used to reduce the effects of temperature on CR.

Sire Infertility

The fertility of the sire can affect CR. Natural service is still being used by many farms and if bulls are not managed properly, CR problems will develop. Artificial Insemination eliminates the problem of bull management, but introduces different problems that can affect CR. With natural service, bulls must be evaluated for reproductive soundness. Evaluation procedures which include a general examination of reproductive organs and semen are reviewed by (21,77). The general health and condition of the bull is also considered. Masculine traits of the bull indicate levels of testosterone, which is an indication of adequate sperm production. Good feet and legs are needed for mounting. Of all the reproductive organs, the size, shape and tone of the scrotum can give the most clues as to the fertility of the bull. Scrotal circumference is related to sperm production and should be about 41 cm for a mature Holstein. Internal accessory glands can be palpated to identify enlargements which may signify an infection. An evaluation of semen should be part of the breeding soundness exam and should determine concentration, percent live, morphology, and motility of sperm in the ejaculate. A bull ejaculate should be between 5 and 15 ml in volume and contain 800×10^6 to 1200×10^6 sperm per ml, 75% live cells and 85% normal morphology. Lower levels of any of these factors will cause reduced fertility. The cow to bull ratio should be no more than 25 to 1 for best results.

Artificial Insemination eliminates the management problems associated with natural service, but problems with semen quality and AI technique can effect CR. Saacke (66) concluded that the quality of semen used in AI is influenced by the male producing the semen and human's interaction with that semen. The goal of any AI organization is to provide the best quality and quantity of semen possible. However, differences in the fertility of bulls used in AI have been observed, and the reasons for these differences have been investigated. Davidson and Farver (15) utilized a 2500 cow dairy and bulls from seven AI organizations in California to study the CR of bulls. Only bulls that had 30 or more first services were used in the analysis, which resulted in a data set of 1605 cows bred to 18 bulls. The CR for bulls ranged from 34.1 to 71.1%. Bulls were divided into low, medium and high CR groups of less than 50, 50 to 60, and greater than 60%. After 30 total services, bulls did not change CR groups with increased inseminations. Cows bred to the high group produced 667 kg more milk than those bred to the low group. The meaning of this difference is unclear except that a higher yield of milk was apparently not deterimental to CR. No association was found between inseminator and CR group and no significant differences among CR groups were seen for Predicated Differences and semen costs. Average days open for the low, medium and high groups were 109, 92 and 85. Senger et al. (71) utilizing 10 bulls from one AI organization in herds found that with 40 inseminations 70% of the bulls were correctly classified into high (more than 55%), medium (50 to 55%) and low (less than 50%) CR groups. With 300 services, 90% of the bulls were classified correctly. The range of CR was 47 to 62%, with a difference of 11.6% in CR between high and low groups. Taylor (85) found that CR decreased for bulls more than 8 yr old and for higher priced bulls. In contrast, Stevenson (82) found no effect of service sire on CR for 732 inseminations and 20 bulls, which may indicate the importance of having a large number of inseminations per bull.

An evaluation system being developed by researchers at NC State University gives dairy farmers a tool to use in evaluating a bull's influence on CR (12,13,48). This evaluation is known as Estimated Relative Conception Rate (ERCR). Conception rates are determined by DHI information from the previous 3 yr. All services are considered for the first 2 yr as long as a calving takes place within a reasonable CI. The third year utilizes 90 d non-return rates to include recently released bulls in the analysis. The model for analysis removes differences in bull fertility due to herd management, year and season. Therefore ERCR is applicable to the average cow, and bulls can be compared more fairly. The average ERCR evaluation is 0, with a range of -10 to + 5, with positive evaluations reflecting a higher CR. A bull needs 1000 services before an ERCR is published. Ninety percent of all bulls have an ERCR between -3 and + 3. No relationship between ERCR and production or type traits has been found. Dairy farmers need to be concerned about bulls with an ERCR of -3 or less because these bulls will probably not improve in CR in the future and are less likely to achieve conception than bulls with a higher ERCR.

Semen Handling

A .5 ml straw of semen should contain a minimum of 10 million motile cells at the time of insemination (65,66,77). Many factors can effect the number of motile sperm at insemination, with the freezing and thawing process having the largest effect after the effect of different males. Dairy farmers are not involved in the freezing process but with the decrease in number of AI technicians, they can affect semen quality and quantity through the thawing process. Senger (68), in a review of semen handling research, identified four areas in which temperature and temperature changes affect sperm; transfer of semen between semen tanks, manipulation of semen within the tank, thawing semen for use, and exposure to varying post-thaw temperatures. Straws of semen are stored in liquid nitrogen at -196 C and temperatures above -80 C begin to affect sperm motility (50). The percent of motile sperm begins to drop after 1 min and is very low after 2 min when the straw is exposed to 20 C after thawing. Straws within goblets are less affected by this change in temperature. Temperatures also increase in the neck of nitrogen tanks and prolonged exposure to that area is harmful. The amount of nitrogen in the tank affects neck temperatures. With full nitrogen tanks, temperatures change less, 15 versus 72 C for straws held in the neck for 1 min. Therefore, repeated raising and lower of straws in tanks containing low levels of nitrogen may have negative effects on sperm. The importance of proper semen tank maintenance, including monitoring of nitrogen levels was described in a review by (70).

Many methods of thawing semen are recommended and vary among AI organizations. The method of semen processing dictates how the semen should be thawed (50). Different thawing methods have been examined, with temperatures and length of time the most important variables studied. Stevenson (82) found a 10 to 11% unit increase in CR for semen thawed in 65 C water for 7 s and 35 C for 30 s compared to semen thawed in the insemination rod. Almquist (1) reported that 66 d non return rates were higher for straws thawed in 35C for 30 s compared to 12 s. The most recommended method of thawing semen is in a 35 C water bath for 1 min. However, AI organization recommendations should be followed (50).

After thawing, additional factors can influence CR. Post-thaw procedures were reviewed by Saacke (65) and Sorenson (77). Cleanliness of equipment is important. The straw should be dried completely and placed in a warmed insemination rod. A 90 degree cut of the straw is necessary for the sheath to form a seal with the straw and prevent semen leakage during insemination. Insemination should take place as soon as possible after semen thawing.

Artificial Insemination Technique

The change from professional AI technicians to herd technicians has brought about a greater awareness of the importance of AI technique and its effect on CR. The site of semen deposition and semen deposition techniques are primary areas of concern. Unlike the bull who deposits 5 billion sperm in the vagina, AI straws usually contain 15 to 20 million sperm which should be deposited anterior to the cervix to bypass the primary barrier of sperm transport. Marshall (45) reviewed AI techniques and concluded that misplacement of semen usually occurs by one of three methods. The insemination rod is inserted too far up one uterine horn. One uterine horn is blocked off by manipulation inside the cow, thus semen does not move up the horn. The insemination rod is withdrawn during deposition so that semen is deposited in the posterior cervix or vagina.

Because the AI straw contains in the order of millions instead of billions of sperm, it can be concluded that deposition has to be beyond the cervix, which acts as a barrier in the reproductive tract. Hunter (39) indicated that the number of sperm per insemination was related to percent nonreturn rates. He divided AI technicians into high and low CR groups and then compared nonreturn rates for inseminations of 20 or 10 million sperm/dose. No difference in nonreturn rates was seen between doses for the high CR technicians. However, low CR technicians dropped from 80.0 to 71.2% with the lower sperm numbers. High CR technicians were able to correctly deposit fewer numbers of sperm, whereas lower CR technicians needed more sperm per dose to achieve high nonreturn rates, which points out the importance of proper semen deposition. Williams et al. (90)

reported semen deposition in three different areas of the tract. Sixty-six cervical inseminations had CR of 39.4%, 975 uterine body inseminations had 48.1% CR and 874 bilateral inseminations at 2.5 cm into the each uterine horn had a CR of 49.3%. Gwazdauskas et al.(29) reported semen in the vagina, cervix or uterine body and found a CR of 10.0, 35.2 and 52.6%, respectively. Additional work by Gwazdauskas et al. (31) indicated a 48.3% CR for uterine body deposition as compared to 26% for cervical deposition. Stevenson et al. (82,83) investigated the effect of ease of cervical penetration on CR. A subjective evaluation of easy or normal cervical penetration at insemination was used. Easy penetration tended to have 21% lower CR. This subjective evaluation of penetration may have reflected the expertise of the inseminator as well as the tonicity of the cervix. The inseminators may have thought they had passed the cervix when they probably had not. In contrast, Hahn (33) found that CR tends to decrease with difficult cervical passage during AI. These studies point out the problems associated with penetrating the cervix and depositing semen in the uterine body.

There is some question as to where the semen can be deposited beyond the cervix. A cow will ovulate about 40% of the time on the left ovary and 60% on the right. Therefore, it may be beneficial to deposit semen on the side of ovulation to increase CR. Senger et al. (69) deposited one-half of a straw of semen into each uterine horn. They found that CR was 64.6% for horn inseminatation and 44.7% for uterine body inseminations. The AI technicians used in this study utilized body breeding for 6 mo and then switched to horn breeding. Technicians were re-trained in proper techniques before each 6 mo period. Once trained to the horn breeding technique, inseminators tended to remain more consistent in their placement of semen as evaluated by radiography. Momont et al. (47) found that CR was not statistically different between heifers where semen was either deposited in the uterine body (68%), the horn contralateral to ovulatory follicle (75%), or the ipsilateral (65%). Horn breeding tends to increase CR because semen is deposited farther away from the cervix and decreases retrograde flow of semen out of the reproductive tract. If proper AI techniques are followed, there appears to be little difference in horn or body breeding CR.

Problems of Detection of Estrus

For a chance of successful insemination, estrus must be detected. Although the cow may be partially responsible for not showing obvious signs of estrus, poor management is the primary reason for reduced ED efficiency. Barr (3) concluded that Ohio dairy farmers increased DO by 40.3 d because of missed estrus periods. Approximately 53% of all estruses were missed. Anestrus and embryonic loss accounted for the cow's influence on poor ED, but poor estrus observation was the largest component. Pellisier (58) estimated that on 24 California dairies, one out of six estrus periods was missed after the first postpartum estrus was recorded. Spalding et al. (78) found an average interval of 41 d between first and second service and 40 d between second and third service on New York dairy farms. Thus, one estrus period was being missed between services. Bozworth et al. (5) divided herds into short (360 to 374 d) and long (greater than 401 d) CI groups and found that the short CI group detected 17% more heats between 17 and 24 d intervals. Stevenson (82) concluded that estrus could range in intensity from pronounced standing estrus to silent estrus. Factors affecting the intensity of expression of heat included group size, housing facilities, proper training for careful observation, use of records, and frequency of observation periods.

Estrogen is the hormone responsible for estrus and many of the factors which influence ovulation will also affect estrus and estrus expression. Britt and co-workers (9) examined the effects of estrogen on the expression of estrus. Thirteen lactating Holstein cows, 4 to 6 wk postpartum were ovariectomized to remove the source of estrogen. Cows were primed with progesterone for 5 d followed by administration of estradiol benzoate 36 h later to induce estrus. Observation for estrus occurred at 8 hr intervals. Cows were observed for 30 min on dirt and 30 min on concrete. The dosage of estradiol benzoate influenced the length and expression estrus. Higher levels of estradiol benzoate and more frequent administration induced longer and more active estrus periods. This information suggested that the level of estrogen produced by the follicle affects the expression of estrus. One mg of estradiol benzoate was given to approximate actual estrus activity of the cow.

During each observation period estrus activity was monitored. Mounting and standing activity was different between the two locations. Cows on the dirt lots expressed more estrus activity for a longer period of time. Some cows expressed little estrus activity on concrete, but more on dirt. The movement of cows to different locations aroused sexual activity. Standing and mounting behavior was not influenced by postpartum interval, season, or milk yield in this study.

Fonseca et al. (24) determined that the first ovulation occurred at about 3 wk postpartum in normal cows. Average days from calving to first detected estrus was 66.9 d and was affected by clinical postpartum abnormalities and milk yield. Although ovulation occurs at 3 wk, little expression is noticed. Blake et al. (4) suggested that the relationship between production and reproduction is seen through less overt estrus symptoms in cows suffering from negative energy balance. Negative energy balance has a detremental effect on the hormones of the estrous cycle. Smith (75) concluded that the cows differ in the intensity and frequency of estrus, and he attributed poor estrus detection to people problems rather than cow problems. Zemjanis (92) found that about 90% of cows reported by dairy farmers as being anestrus were actually cycling, which indicated that the visual signs of estrus were missed by the farmer. Lauderdale (41) concluded that poor estrus detection is related to observation failures.

Foote (25) suggested that the best single indicator of estrus is the cow standing to be mounted by another animal, which is known as "standing heat" and is considered the primary sign of estrus. However, not all cycling cows display a clear standing heat, and secondary signs of estrus such as bawling and restlessness have to be recognized. Figure 1 lists signs of estrus commonly used by dairy farmers. Esslemont et al. (21) concluded that there is a 90% certainty that a cow observed in standing heat is truly in estrus. No other sign of estrus indicated estrus with as much certainty. The number of cows in estrus simultaneously affected estrus activity. When three or four cows were in estrus at the same time, more estrus activity was noticed. Furthermore, 65% of cows were in estrus during the night, which added to the difficulty of detecting estrus during the day. Estrus detection aids have been developed to help reduce the problems associated with estrus detection and therefore increase the number of estruses detected. Estrus detection aids have been reviewed by (7,21,25,75,77) and are listed in Figure 1.

Stevenson and Britt (80) detected estrus using three methods and compared efficiency and accuracy of detection of estrus rates rates. Thirty-one cows were observed and served as controls, while 33 cows were detected with a rump-mounted heat detection device. A final group of 24 were exposed to a testosterone-treated marking heifer. Progesterone was measured to determine accuracy. No difference in efficiency was seen between groups; approximately 55% of all estruses were detected in each group. Accuracies for each group were 68, 66 and 79%. However, cows were only allowed to interact among themselves or with the the treated heifer for 2 to 3 h/ d, which may have limited the usefulness of the detection aids. In groups that used aids, only 27 and 37% of estruses detected were by standing, indicating that observers depended on aids for detection rather than visual observation of standing or other secondary signs of estrus. They suggested that estrus detection aids be used only to supplement careful observation. Holmann et al. (37) evaluated the economics of fourteen methods of estrus detection. Combinations of routine daily observations and estrus detection aids were compared. If CR was high, the use of estrus detection aids became more economical because more cows become pregnant sooner after calving, thus lowering DO. They suggested that the most economical method of estrus detection is the use of tail paint or heat mount devices along with routine visual observation.

Signs of estrus	Estrus detection aids
Standing to be mounted	Tail paint and chalking
Mounting and riding other animals	Heat mount devices
Licking and rubbing other animals	Accurate cow records
Rough or rubbed tailhead	"Heat" expectancy lists
Mud on hips and back	"Heat" detector animals
Restless and nervous	Reproductive tract palpation
Reduced milk yield and letdown	Prostaglandin
Reduced feed intake	Milk progesterone tests
Vaginal mucous discharge	Vaginal electronic probes
Bawling	Pedometers

Figure 1. Signs of estrus and estrus detection aids.

Materials and Methods

Program Development

The ES was developed using the PC Expert Professional (Appendix A) shell program. The ES shell is a self-contained program that interacts with Turbo Pascal 5 (Appendix A) to provide greater flexibility in inputting data, programming computations, and setting up display screens. Furthermore, the use of Pascal allows for the ES to be compiled with the Pascal compiler, which saves expense and provides a compiled version for users at no additional cost to them. Many shell programs require the purchase of compiler, "run-time" modules, or a shell for each user. The shell program provides a text editor into which IF-THEN rules are written. Pascal is used as an interface between the shell and the user. Numeric calculations are performed in Pascal, while heuristic knowledge (non-numeric rules) is written in the shell program because of the greater ease in which the shell program can use this type of information. The ES will run on IBM compatible personal computers from a hard or floppy disk. Screens contain user input instructions and program directions to make the ES easy to use. The program is designed to be used by extension personnel who may or may not have a computer background. The facts and knowledge of the ES primarily come from two sources. An expert within the field of dairy herd reproductive management provided much of the information and, where possible, information, recommendations, and suggestions were supported by research through DHIA information and theoretical models.

Reproductive performance data is available from the Dairy Records Processing Center in Raleigh, NC for all herds in DHIA. The DHIA 202 Herd Summary sheet is used to provide information about the herd's reproductive performance over the last 12 mo. Information from the 202 sheet is entered into the ES from the keyboard. In addition, the ES has the ability to read Direct Access to Records by Telephone (DART) reports. Seven DART reports are captured as ASCII files and analyzed by the ES. Finally, the ES generates a series of specific management questions to further identify problems. The questions are answered yes/no or by multiple choice. Recommendations and suggestions are given on how to improve reproductive efficiency. The ES is divided into three components of which only one will be loaded and evaluated, the other two remaining optional. Evaluation of one area reduces the amount of data entry and prevents the user from being saturated with too much information.

Initial Evaluation of Reproductive Parameters

The initial herd reproductive analysis determines if and where a problem exists. The ES investigates the management component of CI, which is DO. The length of DO is affected by three areas; the number of days to first insemination, whether conception occurs, and the number of estruses detected. Figure 2 depicts the relationship between DO and the three areas that influence DO. For computer programming purposes, each area that affects DO is considered to be mutually exclusive; however, from a biological standpoint, each area actually influences the other and may not be separated. Each of the three areas that influence DO is a small ES which contains important information about the specific area being investigated.

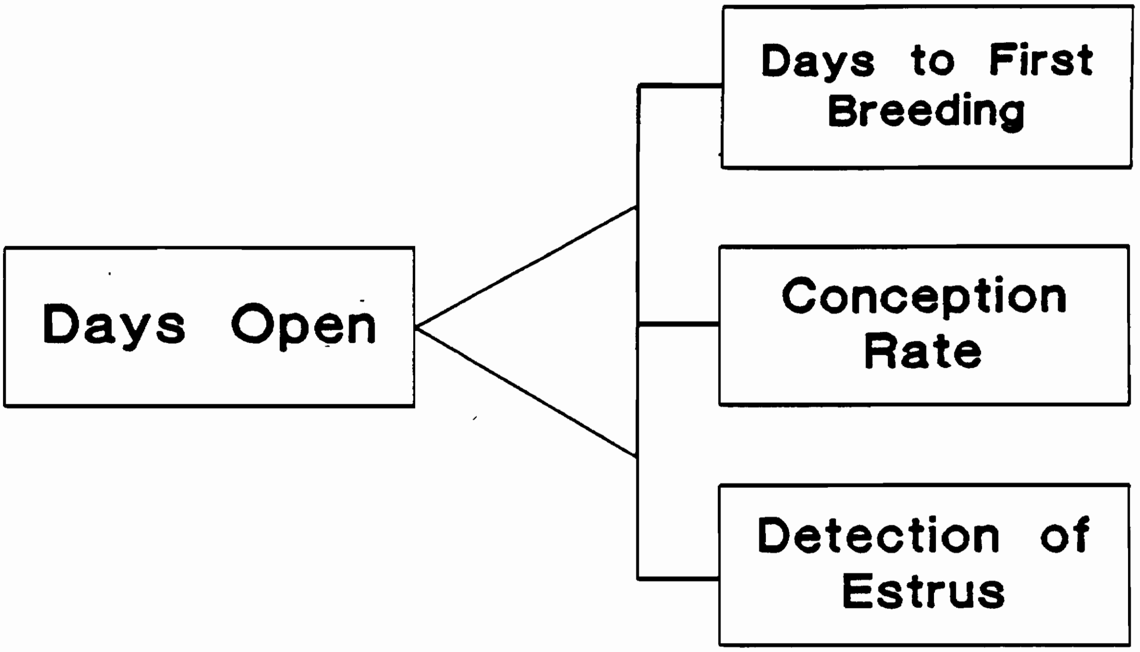


Figure 2. Diagram of areas that influence days open.

Average days open, average days to first service, percent of possible heats observed, and the number of services per conception represent the values needed from the DHIA 202 Monthly Herd Summary. Breedings per conception is the inverse of CR that is also reported on the DHI 202 sheet. Two breedings per conception is equivalent to a 50% CR, while one breeding per conception is equivalent to a 100% CR. Values used are from the reproductive summary of the total herd portion of the DHI 202 sheet. These values represent the reproductive management conditions and practices for the entire herd over the last 12 mo. If the DHI 202 sheet is unavailable, values can be calculated from individual cow records and entered into the ES. A screen lists the four DHI 202 categories for which values are needed.

To determine which of the three areas needs to be evaluated, interpretation levels are set for ranges of values. Interpretation levels range from ″excellent″ to ″severe.″ All ″excellent″ and ″adequate″ interpretation levels correspond to values needed for the achievement of a 12 to 13 mo CI, which should be the reproductive goal of dairy farms. If all areas are ″excellent″ or ″adequate,″ no reproductive problem exists in the herd and the ES concludes that no further evaluation is needed.

Interpretation levels for DO range from 85 to 145 d and are listed in Table 1. A DO of less than 85 d is interpretated as ″too low″ for two reasons. When DO is less than 85 d, CR will usually be compromised because cows are being inseminated too soon after calving. The ES will evaluate the CR area in this case. If CR, DFB and ED are not affected and DO is below 85 d, the ES suggests that no reproductive problem exists, but profitability could be suffering because the length of lactation is shortened. The ES recommends checking profitability associated with a longer DO. A DO between 85 and 110 d is considered ″excellent″ by the ES. If DFB, CR and ED are rated ″excellent″ or ″adequate,″ the ES concludes that no problem exists and no further analysis is needed. When DO is between 118 and 130 d, a ″slight problem″ exists. A DO between 131 and 145 d indicates a ″moderate problem.″ When DO is over 145 d, which corresponds to a CI of at least 14.3 mo, a ″severe problem″ exists.

Table 1. Interpretation levels for average days open and average days to first breeding.

Interpretation	Average days open	Average days to first breeding
Too low	under 85 d	under 60 d
Excellent	86 to 110	61 to 75
Adequate	111 to 117	76 to 82
Slight problem	118 to 130	83 to 90
Moderate problem	131 to 145	91 to 100
Severe problem	over 145	over 100

The interpretation levels for DFB range from less than 60 d (too low) to greater than 100 d (severe problem). Interpretation levels are listed in Table 1. When DFB is less than 60 d, CR is usually a problem area because cows are not ready to conceive. If CR and ED are not identified as problems, the ES suggests that the lactation curve of the cow is being adversely affected as in the "too low" interpretation of DO. An "excellent" range for DFB is between 61 and 75 d. When CR and ED are also at "excellent" or "adequate" levels, a CI of between 12 and 13 mo can be achieved. Problems begin when DFB is greater than 82 d. A "severe problem" exists when DFB is greater than 100 d. If cows are not first inseminated until 100 d after calving, a 12 to 13 mo CI is impossible to achieve, even if CR and ED are at their highest possible levels.

The interpretation levels for breedings per conception are listed in Table 2. When breedings per conception is under 1.8, CR is considered "excellent." Between 1.8 and 2.0, an "adequate" level of conception is being achieved. The "excellent" and "adequate" breedings per conception correspond to a CR of greater than 50%. If breedings per conception is greater than 2.8, which is equivalent to a CR of approximately 35%, a "severe" conception rate problem exists.

The percent of possible estruses observed, or efficiency of detection of estrus, is available on the DHI 202 sheet. Unlike the other areas that have been described previously, the percent of possible estruses observed reported by DHI can be manipulated to appear better or worse than the true ED. For example, the number of breedings per conception is computed by dividing the percentage of successful inseminations into 100. This calculation is not based upon any management practices. Percent of possible estruses observed is calculated by dividing the number of estrous cycles that are possible after the herd's voluntary waiting period (VWP) into the number of estruses that are serviced, or observed, and reported to DHI. The VWP is the number of days after calving the farmer waits before inseminating a cow. Estrous cycles are counted every 21 d after the voluntary waiting period ends until the cow is reported pregnant. The dairy farmer can set the VWP to any number of days. A default of 60 d is used by DHI if no VWP is reported.

Table 2. Interpretation levels for breedings per conception and percent of possible heats observed.

Interpretation	Breedings per conception	Percent of possible heats observed
Excellent	under 1.80	over 70%
Adequate	1.81 to 2.00	60 to 69
Slight problem	2.01 to 2.30	50 to 59
Moderate problem	2.31 to 2.8	40 to 49
Severe problem	over 2.80	under 40

The percent of estruses observed can be influenced by several management practices and decisions. The VWP has great effect on ED calculation. If a dairy farmer is not waiting as long as the stated VWP to begin inseminating cows, the ED figure will be inflated. The DHI calculation for ED begins counting estrous cycles after the VWP but uses all inseminations and reported estruses during and after the VWP. If a dairy farmer is waiting longer to inseminate cows than the VWP used by DHI, the ED calculation will appear to be worse than actuality. The use of natural service and failure to report all observed estruses will also influence the DHI ED calculation.

Interpretation levels for ED efficiency are listed in Table 2. If 70% or more of estruses are detected, an "excellent" condition exists. When ED efficiency is below 40% a "severe problem" with detection of estrus exists. The initial ED interpretation levels are set with the assumption that the figure reported by DHI is correct and not being manipulated by management practices and decisions.

Interpretation levels and corresponding ranges for all four reproductive values used in the intial ES evaluation are set for use in Virginia dairy farms. However, the ES allows for adjustments to interpretation levels. Before the evaluation begins, a description is given of how the four areas will be evaluated. If the user wants to change interpretation levels of one or all of the four values, a screen displaying interpretation levels for each area is generated. The user can then make changes in interpretations that the ES will use in the evaluation. A warning is given to make sure that the new interpretation levels are realistic. This ES feature allows the program to be used in states other than Virginia. For example, 1.8 breedings per conception is considered "excellent" in Virginia. In Texas or Florida, 2.0 breedings per conception may be considered "excellent" due to effects of high temperatures on conception.

Once all three areas have been interpreted, the ES selects one area to be further evaluated. If more than one area is evaluated, the suggestions and recommendations of the ES may not be implemented in the reproductive management program of the farm because too much information regarding possible problems and solutions may be given and nothing will be accomplished. A recommendation is given to concentrate on one of three areas that influence DO. When one area improves, other areas can be investigated. The ES selects the area that needs to be evaluated by comparing the interpretation levels of all DFB, CR, and ED. If all areas are ″excellent″ or ″adequate,″ the ES concludes because no problem exists. If a ″slight,″ ″moderate,″ or ″severe″ problem is found to exist in one of the three areas, the ES will investigate the area that needs the most attention. When all three areas have been interpreted as ″slight″ or ″moderate,″ the ES will evaluate the CR area. When CR and one other area have the same poor interpretation level, the ES will evaluate the CR area. The CR area is selected in these situations because recommendations and suggestions of the ES regarding a CR problem are generally easier to implement and will show more immediate results than correction of the other two areas. In addition, more herd performance data is available for evaluation of a CR problem. If CR improves due to the recommendations of the ES, other problem areas can be investigated and ES recommendations will be more likely to be implemented due to the past success of the ES recommendations for CR.

When ED and DFB are the lowest rated areas, the ES will evaluate the ED area because ED has a large effect on DFB. When ED is rated as ″severe,″ the ES asks questions regarding management practices associated with ED so that ED efficiency can be adjusted, if necessary, to reflect actual farm practices. The DHI calculation for ED efficiency is based on the VWP reported to DHI. The ES attempts to determine the actual VWP by asking how long the average cow is in milk before first inseminated. This new VWP, along with the herd′s DFB is used to calculate a new ED efficiency for interpretation by the ES. The new ED is predicted from an equation which regressed estrus detection probability on DFB and VWP. Data for the regression came from an equation to predict DFB. This equation included VWP so that any calculation took into consideration the influence of VWP on DFB.

$$DFB = \sum_{n=1}^{N} [(VWP + 10) + 21(n-1)]p(1-p)^{n-1} \qquad [1]$$

where

DFB = Days to first breeding

VWP = Voluntary waiting period

n = Service number, Maximum = N

p = Probability of detection of estrus

Equation [1] will predict DFB using VWP and ED probability. A cow should be in estrus approximately every 21 d. Each time a cow is in estrus, there is some probability, p, associated with whether she will be observed in estrus. Half an estrous cycle is added to the VWP because the average cow will have an estrous cycle observed 10 d after the VWP. Equation [1] is a summation of the probability of detection associated with days in milk for a maximum number of services, yielding a DFB for any combination of VWP and ED efficiency.

Equation [1] was multiplied by 1-p and subtracted from itself to create equation [2] that eliminates the summation function.

$$DFB = (VWP + 10)[1 - (1 - p)^N] + 21[(1 - p) - N(1 - p)^N(N - 1)(1 - p)^{N+1}]/p \qquad [2]$$

Days to first breeding for combinations of VWP and ED efficiency were calculated, with VWP ranging between 40 and 90 d and ED efficiency between 10 and 90%, both in increments of five units. The maximum number of estruses that a cow should have during a lactation was set at seven. It was assumed that after seven estruses without an observation a cow will most certainly be culled. Equation [2] was used to develop a table of DFB for all possible combinations of VWP and ED. The DFB table and VWP values were then used in a regression equation to predict ED. Both the linear and quadratic forms were fit in the regression analysis. Regression equation [3] is used in the ES to calculate a new ED efficiency.

$$ED = 93.3 - 2.44152(DFB - VWP - 10) + .0210172(DFB - VWP - 10)^2 \quad [3]$$

Equation [3] had an r^2 of .979. The linear SE is .1537894, whereas the quadratic SE is .0023967. At 58 d beyond the VWP, ED efficiency reaches a minimum value of 25% and then begins to rise slightly. This rise is due to extended DFB and the limit of seven services in equation [2], where cows never seen in heat begin to be lost from the DFB average because of culling. For equation [3] to be an accurate predicator of ED, all observed estruses have to be recorded, even if no insemination takes place. Natural service herds are a problem because estruses are not observed and recorded. The VWP must also be an accurate reflection of farm practices.

When ED is "severe," the ES uses equation [3] to calculate a new ED. The most recently provided VWP figure is used in equation [3]. Before the new ED efficiency is displayed, the ES questions if all observed estruses are recorded and if natural service is being used on the farm. If all estruses are not being recorded or natural service is being used, the ES warns that the newly calculated ED should only be used as an estimate. User interpretation of the estimated ED figure will depend on how accurate herd records are and how extensively natural service is used in the herd. If after the adjustment to ED, DFB, CR and efficiency of detection of estrus are all rated "severe," the ES will make a recommendation to evaluate the CR problem for the reasons described previously.

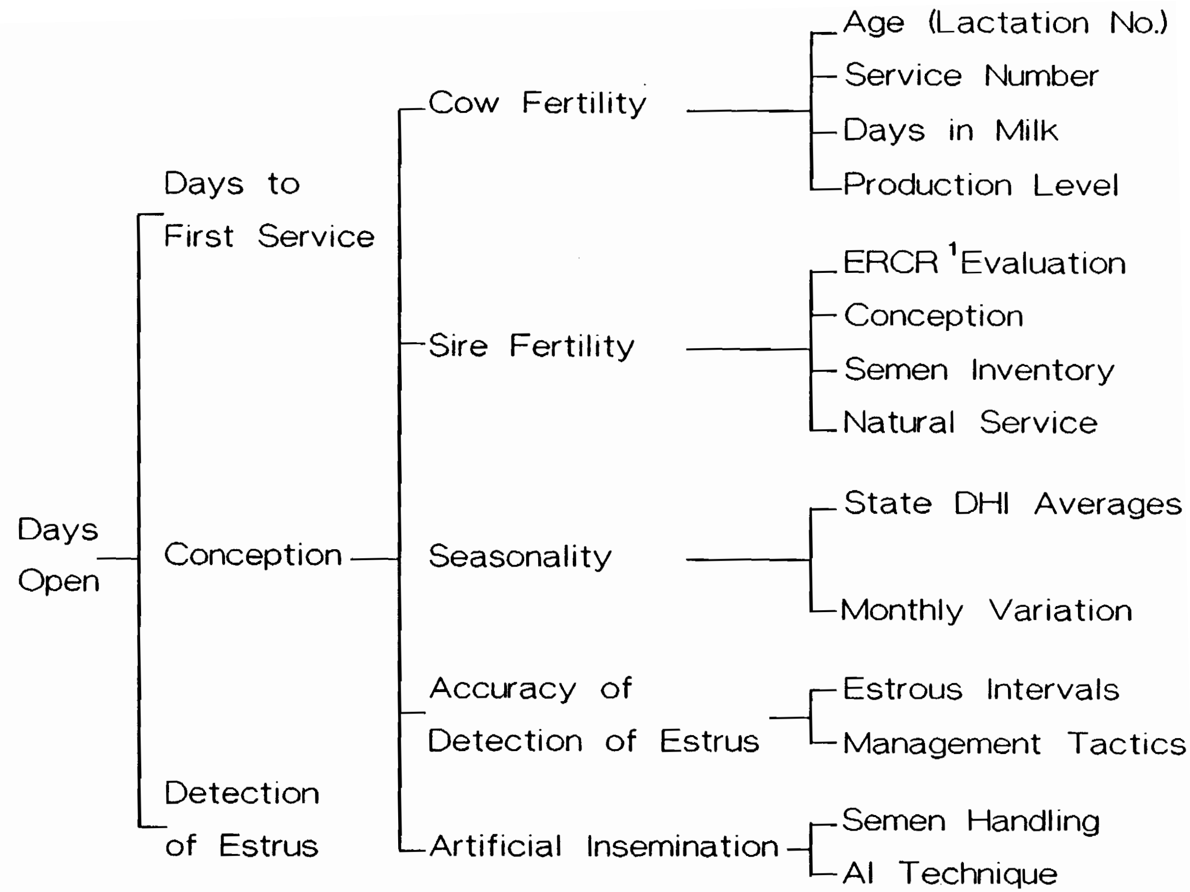
The initial reproductive evaluation concludes by displaying a screen that contains a table that lists the DO, DFB, CR, and ED values for the farm. Herd values, interpretation levels, along with goals for each parameter are included. The ES selects for evaluation the area that needs the most attention. However, the user has the option to select another area for evaluation. The ES loads the portion of the program that will evaluate the area selected by the ES, or by the user.

Evaluation of Conception Rate

Once the ES has concluded that a CR problem exists in the herd, or the user determines that factors affecting CR should be evaluated, the ES loads the CR evaluation program. The general organization of the CR evaluation can be seen in Figure 3. A CR problem can be caused by one, or several, of the five areas that are shown in Figure 3. Each area is evaluated for potential problems.

The ES investigates cow infertility by evaluating standard DHI reproductive reports available through Direct Access to Records by Telephone (DART). The DART system has been developed by the Dairy Records Processing Center in Raleigh, NC. Data for standard DART reports comes from information normally collected on farms and reported to DHI. All dairy farmers on DHI, extension personnel and consultants can have access to DART reports. Information is transmitted by phone between the main computer in Raleigh and terminals on farms or offices. Standard reports available on DART can be used in the day to day management of a dairy farm. Reports can also designed by the user. The DART reports can be captured on a floppy disk as an ASCII file which can then be read by the ES. Standard DART reports used by the ES include: conception rates by lactation, service number, days in milk, service sire, and breed. In addition, a report designed by the reproductive expert which categorizes cows by production level and examines reproductive parameters is used by the ES. Each report contains specific data that can be interpreted by the ES.

The sire infertility portion of the program evaluates two areas. If AI is used on the farm, the ES evaluates the CR by service sire from the downloaded DART report. Sires used on the farm are compared to the ERCR list that is part of the ES. Potential problems are diagnosed and recommendations are given. If natural service is used, the ES evaluates management factors related to natural service and lower CR. These factors include, for example, the health and condition of



[1] ERCR = Estimated Relative Conception Rate

Figure 3. Diagram of evaluation of conception rate.

bulls used in the herd. The ES will identify problems and make recommendations. If no sire infertility problem can be found, the ES concludes that sires are not affecting CR.

The ES uses the report of conception rate by breed, which includes monthly CR by breed of cow in the herd, to evaluate monthly CR. This report is downloaded into the ES with the other DART reports that have been captured. The report contains a CR for each of the last 6 mo. These values are compared to Virginia monthly CR averages for the last 3 yr. Three years of data were used to reduce variability in monthly CR. An accurate monthly CR for 5 yr could not be obtained. The ES detects differences between the state and herd monthly CR by interpretation levels set for comparison purposes, calculating and comparing the rate of increase, or decrease, of the herd and state CR over the same 6 mo period. Differences indicate different herd management conditions. The ES identifies these and other environmental differences, as described in a later section.

The evaluation of accuracy of detection of estrus investigates estrous interval lengths which are available on the DHI 202 sheet and entered into the ES from the keyboard. Management practices which could affect estrous interval length and CR are examined by the ES. The ES makes recommendations on how to correct potential problems.

The investigation of AI technique is divided into two areas. The ES evaluates semen handling techniques used by the farm. Answers to multiple choice questions are used to determine if problems exist, at which time the ES gives suggestions on how to correct the problem. If all answers indicate recommended practices, the ES concludes that the semen handling techniques used by the farm are correct and not responsible for lowering CR. An evaluation of AI technique is then done. The ES displays multiple choice questions regarding AI procedure in an order similar to the actual AI procedure. Answers demonstrating inadequate technique are identified by the ES and descriptions are given on how to improve technique. Otherwise, no problem exists with AI technique and low herd CR is due to some other factor.

Obtaining and Evaluating Herd Conception Rate Data

Conception rate by lactation number, service number, days in milk, breed, and DHI ME-milk rating report for the last 6 mo are available through DART for all herds on DHI. Reports are prepared by DART and are normally printed to a hard copy and evaluated. However, reports can also be captured and stored on a disk as an ASCII file. All reports needed by the ES can be captured in one session of DART. Procedures for obtaining Dart Reports are listed in Appendix B. The DART reports are shown in Appendix C. The ES requests the captured DART file when needed and searches for a specific report by looking for key words within the title of each report. For example, when searching the conception rate by month report, the ES looks for conception, rate, and month. The total number of inseminations, total successful, and CR percentage are listed for each category on the report. For example, the conception rate by lactation report examines the CR for first, second, third, fourth, and fifth and greater lactations. These data appear at the same location in the file each time a report is prepared by DART. Search procedures are written in the ES. The ES obtains the total number of inseminations along with the total successful and then calculates a CR by dividing total inseminations into successful inseminations and multiplying by 100.

For a valid comparison to be made among categories, at least 20 total inseminations are needed for each category being compared. With at least 20 inseminations in the comparison, variation is reduced due to chance associated with conception. If a category has less than 20 inseminations in a comparison, the ES suggests that recommendations may not be totally valid due to the variation associated with less than 20 inseminations. Due to the small herd sizes in Virginia, a validation number greater than 20 was not used. In a group of 20 inseminations, if one more insemination is successful, or unsuccessful, CR changes by 5%. With a smaller group, a change of one would change CR by more than 5%.

A combining procedure is used to group categories for comparison. This increases the total number of inseminations and reduces variation in the comparison. A combined CR is obtained by taking the total number of services for each group and dividing by the total successful. This number is then multiplied by 100 to obtain a CR for the combined group. The combined CR can then be evaluated in the ES. For example, a comparison is made between first lactation CR and the combined CR for second and third lactation. A warning is still given if 20 total inseminations are not used in the comparison.

All other data questions regarding CR asked by the ES can be answered with information from the DHI 202 herd summary sheet. Management questions are answered by selecting appropriate answers from multiple choice questions that are asked. Semen handling and AI technique problems are identified using the answers to management questions.

Conception Rate by Lactation Number

The DART report for CR by lactation contains CR for first, second, third, fourth, and fifth and greater lactations for the last 6 mo. Three CR by lactation comparisons are made. If first lactation CR is 15% higher than the combined CR for second and third lactation, a problem exists. The ES concludes that second and third lactation cows are suffering from negative energy balance. A recommendation to check rations for energy content, check intake, and to score body condition is given. If cows are being scored for body condition, recommendations are given regarding scores.

A second comparison is made between first lactation and the combined second and third lactation CR. If the combined second and third lactation CR is 15% higher than first lactation, the ES concludes that a problem with the heifer rearing program exists. Younger cows should have a higher CR than older cows. The ES recommends checking the age and weight of first calf heifers at breeding and at calving. A recommendation is given to calve heifers at 24 to 26 mo of age.

Weight recommendations for heifers vary with the desired age at first calving. Holstein heifers should weigh approximately 350 kg at 15 mo of age and should enter the milking herd at 525 kg. The rations fed to heifers before calving may need to be checked for protein and energy content. The importance of well-grown heifers is described. If a first calf heifer is still growing during lactation, nutrients needed for milk production and reproduction will be used for growth.

The final comparison of lactation CR is made between the combined CR for for second and third lactations and the combined CR for fourth and greater lactations. If the combined CR for the younger cows is 15% greater than the CR for the older cows, a problem with reproductive culling may exist. The older cows may not be culled as heavily as they should be for reproductive reasons. Older cows become less reproductively sound due to the stress of milk production and calving. Although, no more than 10% of the herd should be culled for reproductive reasons annually, older cows should make up the largest percentage of cows culled for reproductive reasons. The culling practices of the farm may need to be changed so that older "problem" cows are culled, which should increase the reproductive performance of the herd.

If none of the three conditions exists in the herd being evaluated, the ES concludes that CR is not being reduced due to the effects related to the age of the cow.

Conception Rate by Service Number

The DART report for CR by service number contains CR for service numbers one, two, three, four, and five and greater. Conception rates for first, second, and third service for the last 6 mo are used in the evaluation. Fourth, and fifth and greater services are ignored because these groups usually represent a small, select group of reproductive problem cows. A comparison is made of first and second service CR. If first service CR is 15% less than second service CR, a problem exists. The ES makes recommendations to check rations for adequate amounts of nutrients and intake levels. Information is given concerning body condition scoring. The importance of reducing problems associated with calving is described. If more than 10% of all cows in the herd have problems at or during calving, a problem exists and CR will be affected.

First service CR is then compared to third service CR. If first service CR is 15% less than third service, the ES investigates reasons for the difference. Many farmers change breeding policy for third service, which can affect CR. The ES asks if the herd breeding policy for third service differs from first or second service. If the policy is different, the ES will continue to investigate. If the breeding policy is not different, the ES concludes that negative energy balance may be reducing CR, and suggests methods of reducing the effects of negative energy balance on conception. The ES also suggests that cows may not be ready to be inseminated at first service because uterine involution may not be complete. Three questions regarding third service breeding policy are generated if a different policy is being used. The first question determines if gonadotropin releasing hormone is given with third service. If the hormone is given, the ES concludes that ovulation is being controlled so that third service would better correspond to ovulation. The detection of estrus accuracy of first service may not be as precise without the use of the hormone. Recommendations are given on how to improve the accuracy of detection of estrus. If the hormone is not being used on third services, the ES describes how the hormone may help conception rates by improving the timing of ovulation. The second question asks if young sires are used more frequently on third service than first. If so, the ES will suggest that the low CR on the farm is due to poor semen handling and AI technique. Young sire semen usually contains more sperm, which may mask the effect of poor technique. The third question asks if natural service is used on 50% or more of all third services. A higher third service CR due to natural service indicates poor semen handling and AI technique is probably responsible for the low first service CR. The ES will review the semen handling and AI technique used on the farm. If a different third service breeding policy is used, but the ES cannot determine the policy with three questions asked, a recommendation is given to discuss the policy with a reproductive specialist.

If there is not a 15% difference in CR between first and second, and first and third service, the ES concludes that no particular service number is reducing herd CR.

Conception Rate by Days in Milk

The DART report for CR by days in milk contains CR by groups of cows with different days in milk. Days in milk is divided into nine groups for comparison purposes. Less than 50 d is the first group with each group thereafter being 50 to 59 d, 60 to 69 d, 70 to 79 d, 80 to 89 d, and 90 to 99 d. The groups after 100 d are 100 to 119 d, 120 to 149 d and greater than 150 d. A CR for each group is calculated. All inseminations are included in the CR calculation for a specific group of days in milk. For example, if a cow was inseminated at 75 d and returned to estrus at 96 d, and conceived, both inseminations and one pregnancy would appear in the report. The first service at 75 d was unsuccessful, while the second at 96 d resulted in a pregnancy.

Two comparisons are made of CR by days in milk. The first comparison is between the combined CR for less than 60 days in milk and the combined CR for days in milk between 60 and 90. If the CR for less than 60 d is 15% less than the CR for between 60 and 90 days, the ES indicates that cows inseminated before 60 d were probably not ready to conceive. Uterine involution is being delayed by dystocia, retained placentas, stress, or poor nutrition. The importance of uterine involution to CR is explained. The ES suggests that if 10% or more of all calvings are associated with some type of abnormality, an investigation of farm policies associated with calving and calving problems may be needed.

A second comparison is made between the combined CR for less than 100 days in milk and the combined CR for greater than 100 days. If the combined CR for less than 100 d is at least 15% less than the pooled CR for greater than 100 d, a problem exists with negative energy balance. The ES describes problems associated with negative energy balance. The effects of negative energy balance are less after 100 days in milk because daily intake has increased and production has started to decrease. The ES recommends that energy and intake of the ration be monitored during the first 2 mo of lactation. The importance of body condition scoring and the effect of length of the dry period are also described.

If no differences can be found among days in milk for the combined CR, the ES concludes that the effects related to days in milk are not lowering CR. The ES suggests that the low herd CR is probably due to poor semen handling or AI techniques.

Reproductive Performance by DHI Rating

The DART reproduction report categorized by DHI rating, created by the extension reproductive specialist for the state of Virginia, divides the herd into major and minor production groups. The three major groups that are evaluated by the ES are "A" and "B" rated cows, "C" rated cows, and "D" and "E" rated cows. Letter ratings for individual cows are based on the current 305 d 2x ME record for each cow, adjusted to 3.5% FCM. This 3.5% FCM record for each cow is divided by the 3.5% FCM lactation average for the entire herd. Cows rated "A" are 110% of the herd average, while "B" rated cows are between 100 and 110% of herd average. The "A" and "B" rated cows represent the highest producers within a herd. Cows rated "C" and "D" are 90 to 100%, and 80 to 90% of herd average, respectively, and are considered average to low producers. The "E" rated cows are less than 80% of herd average and usually represent potential cull cows. Each major group is made up of three minor groups. Minor groups represented are first, second, and third and greater lactations. Information available on the report includes the number of cows in each minor group and major group, milk weights, projected lactation averages and reproductive information. Average days open, days to first breeding, number of breedings per conception, and length of estrous intervals represent the reproductive values that are obtained and evaluated by the ES. This report is useful in comparing the reproductive efficiency of high and low producing cows in different lactations. Various areas besides CR can be diagnosed from this DART report.

The ES determines if there is a difference in DO among "A-B" rated cows (first major group), and the combined average of the "C" rated cows (second major group), and "D-E" rated cows (third major group). If the first group has a DO that is more than 24 d longer than the combined average of the second and third group, the ES concludes that a problem exists. The ES suggests that the effects of increased milk production may be lowering the reproductive efficiency of the highest producing cows. The ES recommends that the stress of milk production needs to be reduced through proper nutrition. More attention may be needed to the detection of estrus in high producers. The ES then begins an evaluation of DFB, CR and estrous intervals between the first major group and the pooled second and third group. If no difference in DO is found, the ES still investigates the other areas as a problem may still exist.

Average days to first breeding are compared between the first major group and the combined remaining groups. If the high producing cows have DFB that is 12 d longer than lower producing cows, a problem exists and the minor groups are compared within the "A-B" rated major group. If there is no difference in DFB between major groups, the ES will not evaluate the minor groups and states that there is no difference in DFB among major groups and DO of high producing cows is not being extended due to problems related to DFB. If a problem exists, each minor group's DFB is compared to the DFB of the first major group. For each minor group that has a DFB that is greater than the average major group's DFB by more than 12 d, the ES suggests ways of improving DFB for the specific minor group identified. If the ES concludes that the first lactation minor group has a problem with DFB, recommendations are given regarding a proper heifer rearing program. It may be that first calf heifers are too small and unable to grow, milk, and reproduce. If the second, or third and greater, lactation group has a DFB that is 12 d longer than the average of the major group, the ES suggests the existance of a negative energy balance problem, and greater attention must be given to detection of estrus. Problems associated with each area are described. If the ES cannot find a difference among the three minor groups, a recommendation is given to increase detection of estrus efficiency for all high producing cows. When there are no differences among the minor groups, the increase in DFB is most likely related to poor detection of estrus.

The ES then compares the number of breedings per conception. The average breedings per conception for major and minor groups is always truncated to an integer on this DART report. If the average breedings per conception for a group is 1.7, the report would record 1. The first comparison is between the "A-B" major group and the combined average breedings per conception for the other two major groups. If higher producing cows require more breedings per conception, a problem exists. The ES describes management practices that will reduce the effects of high milk production on conception. Energy and intake levels of rations should be monitored, especially during the first two months of lactation. The importance of body condition is also described. When the ES determines that "A-B" rated cows have a higher number of breedings per conception, each minor group is compared to the average of the "A-B" major group. If a minor group has more breedings per conception than the average of the major group, the ES pinpoints that group, describes problems, and gives recommendations. When first calf heifers have a problem, the ES suggests that heifer rearing practices need to be examined. When older cows are requiring more breedings per conception, a problem exists with negative energy balance. If there is no difference in breedings per conception among the minor "A-B" groups, the ES concludes that the stress of milk production needs to be reduced in all high producing cows. Management practices that will reduce stress are given.

If there is no difference in the number of breedings per conception among the major production groups, the ES concludes that poor semen handling and AI techniques may be reducing herd CR. High milk production is not lowering CR if no differences can be detected.

The final evaluation from the DHI rating report is a comparison of differences between estrous interval length. By identifying groups of cows with long intervals, more attention and effort to detection of estrus can be given to problem groups. The estrous interval for the "A-B" group is compared to the combined estrous interval of the second and third major groups. If high producing cows have an interval that is 12 d or more larger than low producing cows, a problem exists. Two factors may be responsible for lengthening estrous interval. Cows may not be cycling due to the stress of milk production, for which the ES recommends checking the energy content of the ration and the body condition of cows. More likely, high producing cows may not be observed closely enough for estrus. High producing cows will show subtle signs of estrus for shorter lengths of time. A recommendation is given to observe high producing cows more closely for signs of estrus and to use heat detection aids.

To further pinpoint problem cows, each "A-B" minor group estrous interval is compared to the average interval of the the major "A-B" group. A minor group that has an interval greater than the average by more than 12 d is identified as a problem. Recommendations are given relevent to each minor group. By pinpointing a problem group, more time and effort can be spent on detection of estrus. If there is no difference among the minor groups, the ES concludes that all high producing cows are lengthening the estrous interval.

If no difference is found between major groups, the ES concludes that factors related to milk production are not influencing estrous intervals.

Sire Fertility

The investigation of sire fertility begins by determining whether or not natural service is used on the farm. If natural service is not being used, the ES will bypass the natural service evaluation and go to the AI and sire fertility portion of the system. The ES then evaluates if more than 25% of the herd is bred by natural service. If less than 25% of the herd is bred by natural service, the ES concludes that natural service is probably not the source of poor conception. However, bulls should still be checked to make sure they are mounting and are in good health. If more than 25%

of the herd is bred by natural service, the program will continue to evaluate factors associated with natural service.

The ES continues by questioning if the bull, or bulls, are housed continuously with cows. If not, the timing of insemination may be affected. One reason for using natural service is to eliminate the problems associated with detection of estrus. A bull will catch most estruses, whereas a human usually will not. Bringing the cow to the bull does not eliminate the need for a good method of detection of estrus. The ES indicates that cows may not be in estrus when brought to the bull. Estrus still needs to be observed when this method of natural service is used. The bull must be able to mount cows or conception will never occur. The ES inquires if the bull has been observed mounting cows. If the bull has not been observed, the ES recommends watching and evaluating the bull to see if he can mount and service the female. The importance of sound feet and legs, and the type of surface the cows are on is also discussed. The bull must also be large enough to service the cows in the herd. The ES then asks whether bulls have been examined for reproductive soundness. If not, the ES explains why an exam is important and what should be examined. For example, size and tone of the testicles are important for production of adequate amounts of sperm. If the bull has not been checked for presence of disease, the ES recommends that a veterinarian examine and test the bull. The importance of a vaccination program is also mentioned. If the physical condition of the bull is rated as "average," "poor," or "over-conditioned," reproductive performance may be adversely affected. The ES explains the importance of having bulls in excellent condition. The cow to bull ratio is also examined. If bulls are continuously running with cows, a bull can only effectively service a group of no larger than 25 cows. If the ratio is larger than 25, the ES suggests that an additional bull should be added to the herd. If all questions are answered ideally, the ES concludes that bulls are in good shape, and the natural service program of the farm is adequate. However, a fertility examination may be necessary to determine semen quantity and quality. If semen is abnormal, conception may be adversely affected.

Male fertility, influenced through AI, is examined by comparing the AI sires used on the farm to an ERCR list of 128 sires. The list of 128 sires contains the sire's registration number, code number, and AI organization name, along with an ERCR. The conception rate by service sire report, obtained through DART, is captured on disk. The ES then reads the captured DART file and compares sires used on the farm to the ERCR list. Three separate areas are investigated at this point. The percentage of ERCR sires rated at -3 or below that are used on the farm is determined. If the percentage is larger than 20%, the ES concludes that too many low ERCR sires are being used, which may be affecting CR. A list is provided of the low ERCR sires being used. The ES then looks for sires with at least 20 inseminations over the last 6 mo and examines their CR. Sires with a CR of less than 25% with at least 20 inseminations are displayed and the ES recommends that these sires be avoided or used cautiously. Herd conception rates may be lowered because of the heavy use of low CR bulls. The ES checks the total number of sires being used on the farm. If more than 15 different sires are being used, The ES recommends to reduce the number of sires used. Semen quality can be affected by raising and lowering of canes. If none of the three areas has a problem, the ES concludes that sire infertility due to AI is not a problem for the herd.

Conception Rate by Month

The ES uses the DART conception rate by breed report to obtain a CR for the last 6 complete mo. This report divides the herd by breeds when the herd is made up of more than one breed. The number of total inseminations and total successful for each month by breed are on the report. Totals are given for each breed and the entire herd. This report is captured on DART and downloaded into the ES. The ES combines all breeds and uses the total monthly inseminations and total successful to compute a CR for each month. This monthly CR is then compared to the state CR for the same mo averaged over a three yr period. The state average CR was obtained by using 1986, 1987, and 1988 DHI 202 information for Virginia dairy herds. Months with a CR of 70% or better were eliminated from the data because they probably represent natural service herds and would not reflect environmental conditions associated with AI. Herds utilizing natural service would report a pregnancy to DHI. The cow may have never been observed in estrus. Monthly state CR values are displayed in Figure 4. Before the ES begins the evaluation, an option is given to use Virginia values or enter different values. This feature allows for the ES to be used in other states.

The ES computes a regression of CR on month for both the state and herd CR data using the last 6 mo. The regression equation (slope and intercept) is then used to compute an average CR for each 6 mo period, using mo 3. A one sided t-test is used to test for differences between herd and state for both slope and average CR. The t-test is one-sided because the primary interest is in finding herd values that are below the state values. The following is the t-test used by the ES.

$$t = \frac{(\hat{b} - b)}{s_{\hat{b}}}$$

where

$\hat{b}$ = Herd value (slope or average CR)

b = State value (slope or average CR)

$s_{\hat{b}}$ = Standard error for herd (slope or average CR)

It is considered that the state parameters are measured without error, so the standard error is only from the herd estimates. Interpretation values ranging from "adequate" to "severe" were set for calculated t-values according to type I error probabilities and four degrees of freedom and are listed in Table 3. Problems are defined beginning with $P < .20$ and extending to $P < .01$, representing a "severe" problem. A negative t value suggests that herd values are lower than state values. When a postive t value is obtained, herd values exceed state values and are not considered a problem.

The ES displays a screen which lists herd and state CR for each of the last 6 mo being investigated. A table is displayed that shows the average CR for the herd and state, along with the slope of each regression line. The slope is interpreted as the average change in CR per month. The ES also

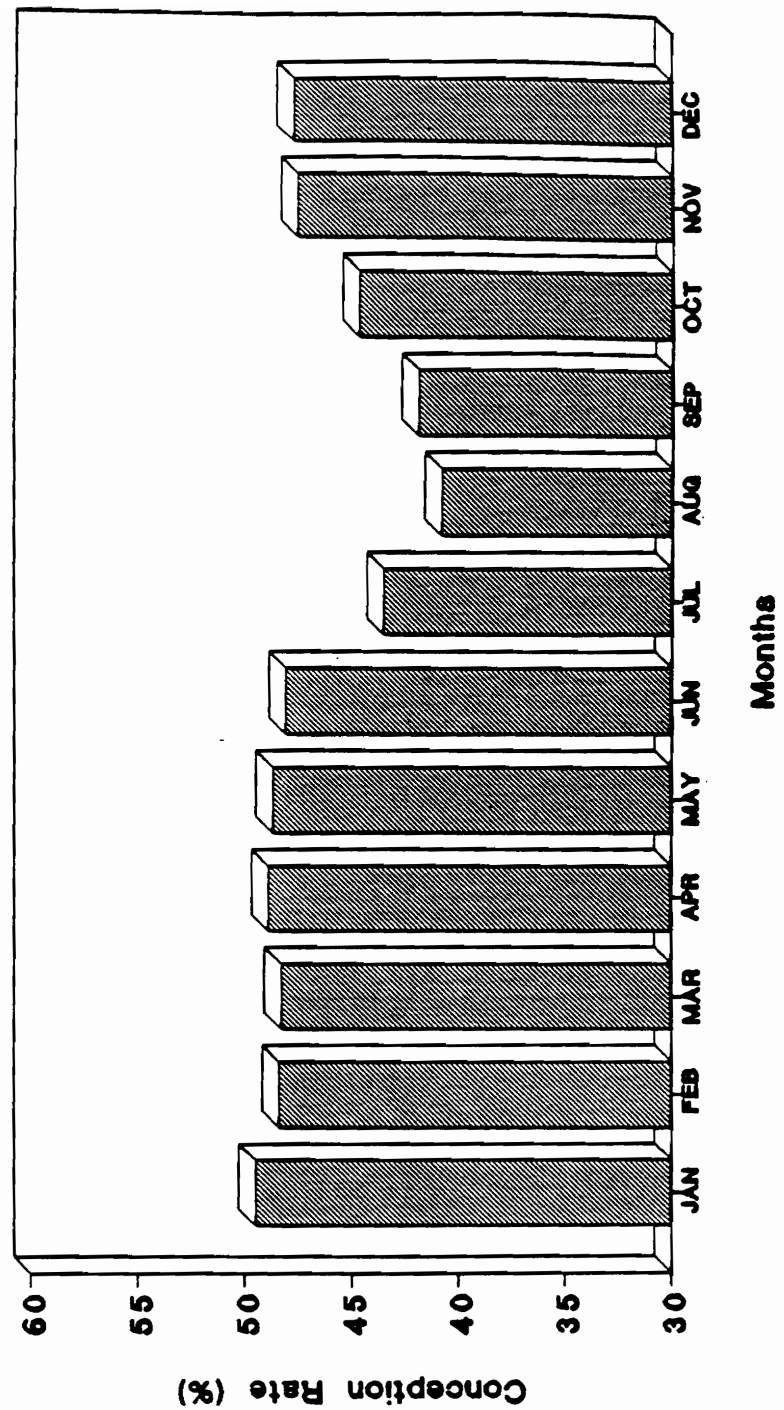


Figure 4. Average monthly conception rates for 1986 to 1988 in Virginia DHI herds.

Table 3. Interpretation levels for t-values of average conception rate and slope.

Interpetation	t-value	p-value
Severe	Less than -3.74	Less than .01
Moderate	-3.47 to -1.53	.01 to .10
Slight	-1.533 to -1.19	.10 to .20
Adequate	Greater than -.941	Greater than .20

provides a word evaluation for the differences between the herd and state values in the table. At this point, the ES can display four different messages about the information depending on the combination of evaluations from the t-tests. When both the slope and average CR are ″adequate,″ the ES concludes that the herd appears to have no CR problem when compared to the state. When the average CR is ″adequate,″ and the slope is ″slight,″ ″moderate,″ or ″severe,″ The ES suggests that the herd CR is declining at a rate which will not allow the average CR to remain ″adequate.″ If summer months are being evaluated, the ES recommends that something should be done to reduce the effect of heat stress on conception. The slope and average CR for the state already accounts for the summer decline in CR, so the herd CR is declining more than the average herd. If no summer months are being evaluated, the ES suggests that the decline in the herd CR may be due to inconsistent AI technique. When the difference between the slopes is ″adequate,″ but the average CR difference is ″slight,″ ″moderate′″ or ″severe,″ the ES suggests that cows in the herd are probably being affected by some factor which is lowering CR. When both the slope and the average CR are ″slight,″ ″moderate,″ or ″severe′″ the ES combines the previouly described recommendations; the CR is too low and declining. An example evaluation screen from the ES can be seen in Figure 5.

Accuracy of Detection of Estrus

The evaluation of detection of estrus accuracy determines if cows observed in estrus are actually in estrus. Cows that are inseminated when not in estrus will not conceive and will therefore lower CR. The ES determines if an accuracy problem exists by requesting the number of estrous intervals between 18 to 24 d, 36 to 48 d, and ″other″ categories found on the DHI 202 form. The ″other″ category represents estrous intervals that are not of the normal length of 18 to 24 d; or 36 to 48 d which represents two normal estrous intervals, one estrus not observed. The number of ″other″ estrous intervals is divided by the total number of estrous cycles reproted. If the percentage of ″other″ intervals is greater than 10%, the ES concludes that an accuracy problem exists and is reducing CR in the herd. The ES describes the accuracy problem. If less than 10% of intervals are

Figure 5. Expert system screen for monthly conception rate evaluation.

CONCEPTION RATES FOR THE LAST 6 COMPLETE MONTHS

Month	Herd	State
NOV	26.32	47.64
DEC	53.33	47.84
JAN	30.00	49.53
FEB	44.00	48.38
MAR	26.32	48.29
APR	46.43	48.89

Measure	Herd	State	Difference
Adjusted Average Conception Rate	37.25%	48.34%	Slight
Average Change in Conception Rate per Month	0.96%	0.18%	Adequate

This herd shows an Adequate change when its monthly conception rate is is compared to the state's change over the last 6 months. However, the difference in conception rates is Slight . This indicates that conception rate should continue to improve. Please identify the low conception rate months and evaluate management techniques.

PLEASE SELECT ANY KEY TO CONTINUE OR "P" TO PRINT "others," the ES concludes that no accuracy problem exists. In both cases the ES continues and evaluates management practices associated with accuracy of detection of estrus.

Three common management practices are evaluated. The ES asks questions when cows are inseminated in relation to the observation of standing estrus. Three choices are given; less than 12 h, 12 h, and greater than 12 h. If 12 h is not selected, the ES describes the problems associated with insemination before and after 12 h. A time less than 12 h will reduce the number of sperm available at the site of fertilization after ovulation occurs and will reduce CR. The next question determines if PG is used on the farm. If PG is being used, the ES asks if cows are bred by appointment after the PG injection. Appointment breeding after PG administration will lower CR. The ES recommends insemination 12 h after standing estrus. Appointment breeding should only be used if cows do not show any sign of estrus. If cows are not bred by appointment, the ES concludes that PG is being used correctly. The third management practice evaluated concerns insemination recommendations based on results of veterinary palpation results. If this practice is being used on the farm, the ES describes the inaccuracy of palpation results and a suggests that milk progesterone test be used to confirm palpation recommendations. All three management practices will increase the percentage of "other" intervals in the herd, but if used correctly, CR will not be adversely affected. If an accuracy problem exists, but none of the practices mentioned are being used, the ES suggests that milk progesterone tests should be used to confirm estrus on suspect and "other" interval cows. If another type of management practice is being used, the ES recommends that the practice be reviewed by a specialist.

The evaluation of accuracy of detection of estrus concludes by stating that CR will improve if cows not in estrus are not inseminated. Management practices can alter estrous intervals, but if used correctly, can improve CR.

Semen Handling and Artificial Insemination Technique

The evaluation of semen handling and AI technique is combined into one knowledge base. The ES begins by generating a list of types of people who usually perform the insemination at the farm. The computer list includes the owner, herdsman, farm employees, and AI technician. The user selects all applicable inseminators. If an AI technician is being used, the ES inquires if more than 80% of the herd is being inseminated by the AI technician. If yes, the ES will conclude that poor semen handling and AI technique should not be lowering CR. The AI technician should be well trained in semen handling and AI technique, however, the ES recommends observation of the technician for proper technique and comparison of the CR among the AI technician's other farms. If less than 80% of the herd is inseminated by a technician, the program continues by determining the number of different people performing inseminations on the farm. If two or more people are used, the ES recommends that a CR for each individual be calculated for comparison. The ES suggests that if a 15 percentage unit or greater difference exists among inseminators, the low CR inseminator may need to be observed and possibly retrained to inseminate cows properly.

The ES continues by evaluating the different components of semen handling. The order of evaluation follows the normal procedure of handling semen on the farm and begins by determing if the semen tank is is maintained and filled with nitrogen on a regular basis. The importance of proper tank maintenance is stressed if no routine program exists. The process of removing straws of semen from the tank is evaluated with three separate questions. The first question inquires if straws are removed from the tank within ten seconds. The second question asks if the cane of straws remains below the frost line of the tank. The importance of removing straws below the frost line within 10 s is described if proper procedure is not being followed. The ES determines how straws are removed from the tank. Possible answers to this question are fingers, tweezers, or split sheath. If fingers are being used, the ES suggests that the use of fingers is acceptable if the straw is removed in 10 s and the cane remains below the frost line.

Thawing procedures are evaluated by choosing one of three possible procedures. If thawing occurs in the air or in the insemination rod, the ES recommends that unless the AI organization that packaged the semen recommends these special thawing procedures, a water bath thaw should be used. The ES inquires about the temperature of the water bath and recommends between 90 and 95 F. However, the recommendations of the AI organization should be followed. The ES then questions if the thermometer used in the water bath has been calibrated in the last 6 mo. If not, the ES recommends checking the thermometer. Finally, the ES asks if actual straw thawing time is less than 30 s, between 30 and 60 s, or greater than 60 s. Proper thawing time is between 30 and 60 s and the ES describes the problems associated with the other choices. In all recommendations and suggestions, the ES describes how sperm and sperm numbers are affected by the specific procedure being investigated.

Post-thaw procedures are investigated by evaluating questions regarding how the straw of semen, AI rod, and sheath are handled after thawing. Seven yes or no questions are generated by the ES. If no is answered, the ES explains why a particular question should have been answered yes. The AI rod and sheath should be warmed before the straw is placed in the gun. The straw should be dried to prevent the adverse effect of water on sperm. The loaded gun should be should be wrapped with a paper towel. A 90 degree cut of the straw is necessary for delivery of maximum sperm numbers. The seal between the straw and sheath should be tight. The plunger should be pushed to the cotton plug of the straw. Once the gun is loaded, it should be protected from environmental temperature by placing it close to the inseminator's body. Finally, the ES determines the time elapsed between thawing and insemination. Three choices are less than 5 min, less than 10 min, and more than 10 min. If less than 5 min is not selected, the ES recommends that insemination should take place within 5 min, and if more than one cow is to be inseminated at a given time, each straw should be prepared individually.

It is possible for all questions regarding semen handling to be answered correctly, at which point the ES concludes that semen handling is not a problem. If a question is answered incorrectly, the

ES recommends making improvements. If questions are answered correctly, the ES will conclude that the AI technique used on the farm is not reducing CR.

Evaluation of Efficiency of Detection of Estrus

If after the initial reproductive evaluation of DHI 202 categories the ES concludes that a problem exists in detection of estrus, the ES investigates detection of estrus on the farm. Figure 6 illustrates the evaluation of detection of estrus. The evaluation begins by obtaining information from the DHI 202 Herd Summary sheet about estrous intervals and number of cows first serviced after 100 days. Three questions regarding estrous intervals are evaluated. The number of intervals between 18 and 24 d, 36 and 48 d, and ″other″ (intervals outside these categories) is entered. If the percentage of intervals between 36 and 48 d is greater than 30% of all intervals, the ES concludes that estruses are being missed due to a poor observation routine. In addition, the ES requests the percentage of cows first serviced after 100 d. If this percentage exceeds 10%, the ES suggests that signs of estrus are not being recoginized or may not be known to the person observing estrus. When the estrus interval and percentage of cows first serviced after 100 d are both over their respective limit, the ES concludes that routine observation and recognition of the signs of estrus are poor. The ES questions if all pregnancies are being diagnosed and recorded, and then describes problems associated with not recording pregnancies and the effect on detection of estrus. For example, if cows are not recorded as pregnant, they will continue to be counted as open and cycling, which will make the percent of estruses observed appear lower than reality. After 60 days post-insemination with no recorded estrus, insemination, or pregnancy, DHI will consider the cow pregnant and remove her from the breeding herd. In this situation, the cow may not be pregnant and still has to be observed for estrus.

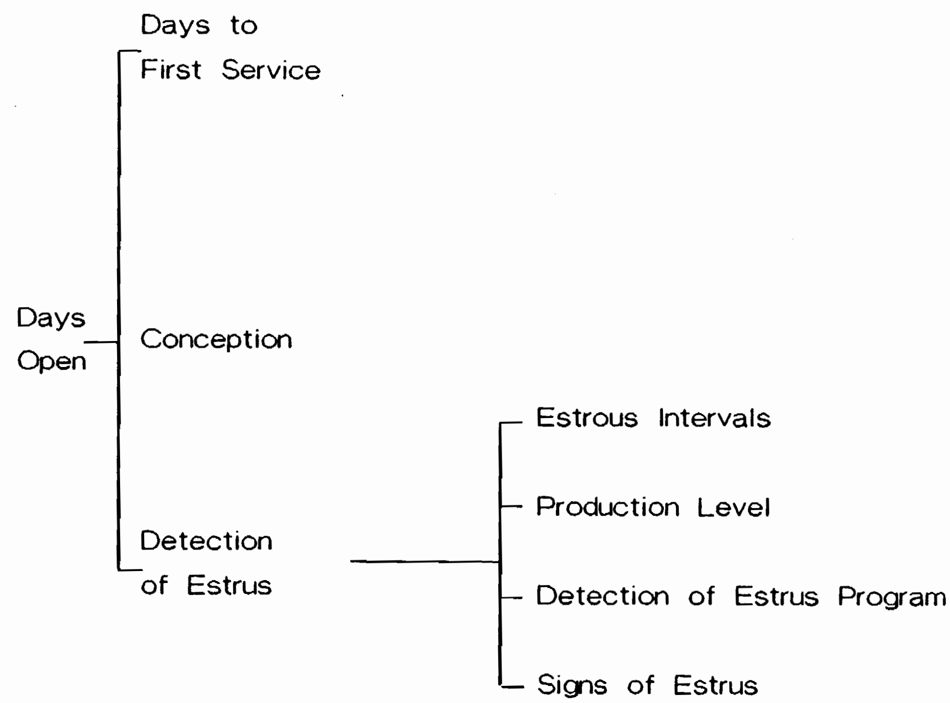


Figure 6. Diagram of evaluation of detection of estrus

The ES then uses the DART reproductive report categorized by production rating (previously discussed) to investigate estrous interval lengths of high and low producing cows in a herd. The report is downloaded into the ES as previously described. If the "A-B" major group of high producing cows has an estrous interval more than 12 d larger than the average of all "C," "D," and "E" rated cows, a problem with detection of estrus exists. The increased interval length can be due to several factors. High producing cows are under more stress than low producing cows and may not be having normal estrous cycles. Recommendations are given on how to lower stress levels through proper nutrition and management. The stress of high milk production reduces the intensity and duration of estrus, which means that more time must be spent observing high producing cows for signs of estrus. Heat detection aids should also be used. To further pinpoint problem cows, the estrous intervals "A-B" groups are compared individually to the estrous interval of all "A-B" rated cows. If a group has an interval that is greater than 12 d larger than the average of the combined group, a problem exists in the individual group. If no differences in interval lengths are found between individual and combined groups, the ES concludes that milk production is not affecting length of estrous interval.

Evaluation of the program for detection of estrus begins by questioning if a routine detection program exists. If no routine program exists, the ES recommends that a twice daily observation estrus program be implemented. The ES then questions topics regarding the components of a good program for detection of estrus. The first question determines how many observation periods are being used. The possible answers to this question are one, two, and more than two observation periods. If the answer is one period, the ES recommends that at least two daily observation periods are needed; however, the ES asks if cows are moved to a special area during the daily observation period. If movement does not occur, the ES recommends that if only one observation is possible, cows should be moved as a group to a dirt lot for observation. This movement will enhance the expression of estrus. If there are two or more daily observation periods, the ES asks if the two observation periods are 12 h apart. If the periods are not 12 h apart, the ES recommends at least two observation periods be 12 h apart. For example, a morning and evening observation should be 12 h apart, with other other periods occurring at other desired times of day. This action assures that cows are being observed at the most ideal times for the expression of estrus to be recognized. The next ES question concerns the length of each observation period. Choices include less than 15 min, 15 min, and more than 15 min. If less than 15 min is selected, the ES suggests that observation periods should be at least 15 min. The ES then inquires where on the farm estrus detection takes place. The choices to this question are free stalls, feed bunk, dirt lot, milking parlor, holding pen, pasture, or other area not listed. If an area other than a dirt lot or pasture is selected, the ES describes advantages of dirt lots and pastures. The ES next inquires as to what type of surface on which cows are standing during observation periods. Concrete, dirt, and neither are given as choices. If concrete or neither is selected, the ES recommends that cows be observed on a level dry dirt surface to increase mounting activity. As an alternative to dirt, the ES suggests that concrete can be used if it is dry and grooved. The final question regarding a routine program for detection of estrus determines whether the people who are watching for estruses have been trained in recognizing the signs of estrus. If the people have not been trained, the ES recommends training all personnel in techniques and signs of estrus. If all questions are answered ideally, and a routine program exists, the ES concludes that the reduced efficiency of detection of estrus is probably related to a poor understanding of the physical signs which indicate estrus. If a routine program did not exist and the questions are answered correctly, the ES recommends that the program outlined by the questions be implemented.

After the program for detection of estrus is evaluated and recommendations given, the ES investigates the signs of estrus being recognized. The user selects all signs of estrus used from a list which includes standing, mounting other animals, bawling, restless and nervous, vaginal discharge, reduced milk yield and off feed. For each sign that is not selected, the ES makes a recommendation to include the sign in the program, and explains importance of the sign and gives suggestions on how to observe the sign. For example, if standing is not selected, the ES will describe the importance of recognizing standing estrus and recommend that an effort be made to improve the recognition of standing estrus. Similar descriptions are made for the remaining signs of estrus not selected. If all signs are selected, the ES concludes that the use of estrus detection aids may be necessary so that signs are seen on a larger number of cows. The ES suggests that if all signs are being observed, efficiency of detection of estrus should improve.

The ES determines whether estrus detection aids are being used. If none are being used, the recommendation is to begin chalking tailheads, using heat mount devices, heat expectancy lists and milk progesterone tests to help improve efficiency of detection of estrus. A reminder that the aids are not a substitute for routine observation is also given. If detection aids are being used, the ES suggests the aids may be replacing a routine ED program instead of complementing. The ES then investigates estrus detection aids. If mount devices are being used, the ES describes some of the problems associated with their use. An explanation on how milk progesterone tests can be used to improve detection of estrus is given. The ES determines if tail chalking is being used. If it is not, it is recommended along with an explanation that chalking is the simplest and least expensive estrus detection aid available. The ES describes how a heat expectancy list of cows can be made and the benefits of using the list.

Evaluation of the program for detection of estrus concludes by re-emphasizing the importance of routine daily observation for estrus. The signs of estrus are reviewed, and the importance and problems of aids commonly used in detection of estrus are also reviewed.

Evaluation of Days to First Breeding

When the ES determines that DFB is the area in need of the most correction, or the user selects the DFB evaluation, the ES calls the DFB program. The DFB evaluation program is the smallest component of ES because the ES will only select the DFB evaluation when DFB is in most need of correction. When DFB, CR and ED are intepreted as being equally in need of attention, the

ES will evaluate the CR area. When DFB and ED are most in need, the ES will evaluate the ED area. Days to first breeding depends on the efficiency of detection of estrus; if cows are not observed in estrus; DFB will be a problem. The ES will evaluate factors associated with an extended DFB, including the influence of the VWP, detection of estrus, cow health, and herd health program of the farm. Figure 7 depcicts the evaluation of days to first breeding.

The VWP in theory is the minimum DFB. The ES begins the evaluation by inquiring about the length of the VWP. Three choices are given: less than 60 d, 60 d, and greater than 60 d. The VWP is recorded on the DHI 202 sheet. If 60 d or greater than 60 d is selected, the ES explains why the VWP should be no more than 60 d. A recommendation is given to begin insemination after cows have been checked ready to breed by a veterinarian at 30 to 50 d postpartum. All DHI rated "B," "C," "D," and "E" cows should be inseminated at the first observed estrus after 50 d postpartum. The ES suggests waiting to inseminate "A" rated cows so that the stress of milk production will not inhibit CR. If the VWP is less than 60 d, the ES concludes that the VWP length is not adversely influencing DFB.

To determine how the farm is using the VWP, the ES asks for the percent of first services that took place before the end of the VWP. These data are available on the DHI 202 sheet. If greater than 15% of first services were before the end of the VWP, the ES concludes that the VWP is being used correctly. If less than 15% of the herd has a first service before the end of the VWP, the ES concludes that the VWP is not being used correctly and may be extending DFB. The ES describes how the decision on when to inseminate should be based upon the condition of the individual cow. The importance of 30 d postpartum checks is described. Recommendations are given to to use the VWP as a guide and not to wait the whole VWP on all cows.

The ES evaluates the effects of milk production on DFB by evaluating the reproductive report which categorizes cows by DHI production rating. This report is downloaded through DART into the ES. The report is evaluated in same manner as in the CR evaluation.

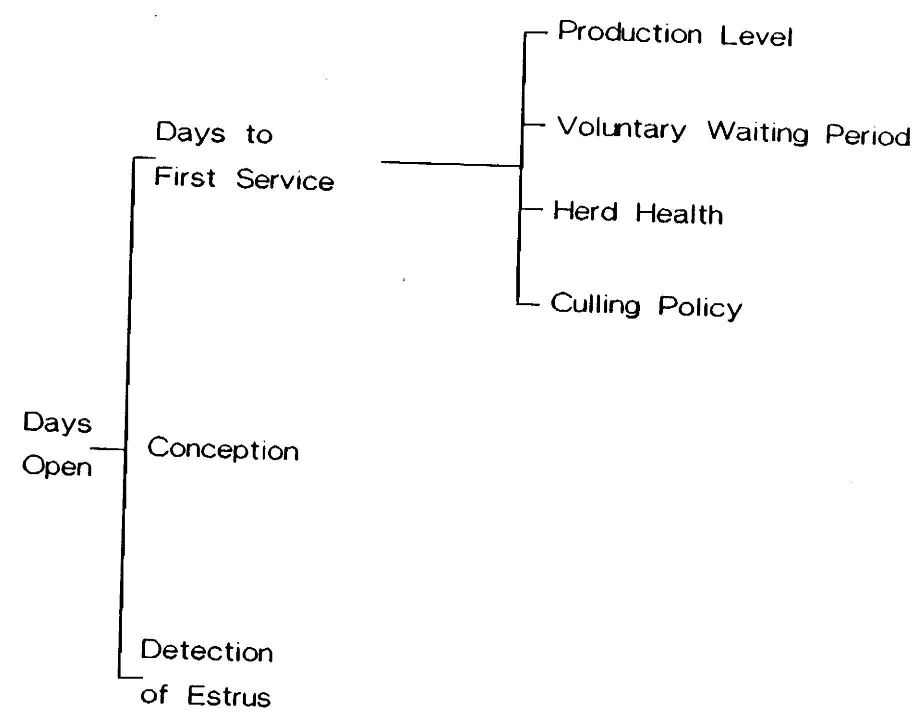


Figure 7. Diagram of evaluation of days to first breeding.

The ES asks if a routine program for detection of estrus exists on the farm. If no program is indicated, the ES recommends implementing a program so estrus can be observed regularly. The ES suggests that the detection of estrus portion of the ES program should be run at the conclusion of the DFB evaluation. Improving the detection of estrus on the farm should lower DFB. If a routine exists for the detection of estrus, the ES suggests that poor detection of estrus is probably not responsible for the DFB problem.

The ES investigates cow effects on DFB by asking three questions regarding cow health. Three choices are provided as possible answers to the questions: less than 5%, 5 to 10%, and greater than 10%. The first question determines what percent of the herd had a metabolic disorder during the first 2 mo of lactation. If more than 5% of the herd had a metabolic disorder, the ES suggests that a nutritional problem during the dry period or early lactation could be causing the metabolic disorders. These disorders will delay estrus, which increases DFB. The second question determines what percent of the herd needed assistance with calving. If more than 5% of the herd needed assistance, a problem exists. The ES suggests that calving difficulties may be related to many factors. Poor nutrition will increase the number of calving problems. The sire, cow, and calf size will also affect calving difficulty. The ES recommends reducing the amount of stress associated with calving by keeping cows in good health, and keeping the calving area clean and dry. The ES then determines what percent of the herd had a retained placenta. If more than 5% of the herd had a retained placenta, a nutritional problem may exist which is causing DFB to increase. Recommendations are given on how to reduce the incidence of retained placentas. The importance of proper nutrition during the dry period is described. The effect of retained placentas on uterine infections is also described. If more than 15% of the herd has a retained placenta, the ES recommends discussing the problem with a veterinarian. If all three questions indicate no problems, the ES concludes that the cow should be in good health and probably not adversely influencing DFB.

A herd health program can reduce DFB by identifying potential problems. The ES inquires if the herd is on a regular health program. If not, the ES describes reasons for having a health program recommends that the herd should take part in a health program with the assistance of a veterinarian.

If the herd is on a program, the ES investigates the components of the program used on the farm. A list of the components of a good herd health program is generated. The list includes a post calving examination, 30 d post-calving examination, 45 d post-breeding pregnancy check, no "heat" cow examination, and problem cow examination. For each component that is not implemented, the ES describes why that examination should be a part of the program. If all choices are selected, the ES concludes that the health program is adequate.

The final question of the DFB evaluation determines if all reproductive culls have been identified on DHI reports so they are excluded from reproductive parameters. Reproductive culls that have not been identified will influence all reproductive parameters being investigated by the ES. However, the greatest effect of not reporting culls is seen in days to first breeding. When the decision is made to cull a cow after she drops below a specified level of milk per day, it is usually reported to DHI when she is finally culled and not when the decision was made to cull. Many times the decision comes before any insemination was performed. Therefore, it is not uncommon to have cows with no breeding dates that have been in milk for a long time. A small number of cull cows that have not been identified will inflate all reproductive parameters, especially in a small herd. The ES recommends identifying all cull cows when the decision to cull is made.

Results and Discussion

Materials and Methods (Journal Article)

Program Development

An expert system (ES) designed for evaluation of the reproductive management and performance of the dairy enterprise was developed using the PC Expert Professional shell program and Turbo Pascal 5 for IBM compatible computers. The shell program contains all heuristic knowledge, whereas Turbo Pascal is used for data collection, numeric calculations, display screens, and compilation of the ES, allowing the user to operate the system without additional software. The program was designed to be used by extension personnel who may not be familiar with computers or reproductive management. Knowledge and expertise for the ES was provided by an extension reproductive specialist and was augmented with parameters estimated from research data.

The ES obtains information for the herd evaluation from several sources. Reproductive performance data is available from the Dairy Records Processing Center in Raleigh, NC for all herds that use this center. The DHIA 202 Herd Summary sheet is used to provide information about the herd's reproductive performance over the last 12 mo. Information from the 202 sheet is entered into the ES from the keyboard. In addition, the ES has the ability to read reports from Direct Access to Records by Telephone (DART). Seven DART reports are captured as ASCII files and analyzed by the ES. Finally, the ES generates a series of specific management questions to further identify problems. The questions are answered yes/no or by multiple choice. Recommendations and suggestions are given on how to improve reproductive efficiency. The ES is divided into three components of which only one will be loaded and evaluated, the other two remaining optional. Evaluation of one area reduces the amount of data entry and prevents the user from being saturated with information.

Initial Evaluation

Reproductive parameters investigated initially are days open (DO), days to first breeding (DFB), conception rate (CR), and percent of possible estruses observed (ED). Each parameter is entered by the user. To determine a problem, interpretations ranging from "excellent" to "severe" were set for each of the four reproductive parameters being investigated (Tables 1 and 2). "Excellent" and "adequate" interpretations correspond to a recommended 12 to 13 month calving interval. If desired, the ranges for interpretation can be changed before the evaluation begins. Average days open indicates the overall reproductive performance of the herd, whereas DFB, CR, and ED are evaluated to identify problems. Figures 8 and 9 summarize the number of Virginia DHIA herds in each category for variables evaluated. There are more herds rated "excellent" than "adequate" for DO. A majority of herds are rated "moderate" or "severe" for detection of estrus. Figure 3 shows the organization and flow of the ES for the CR evaluation. The ES will select for further evaluation only one of the three areas that influence DO.

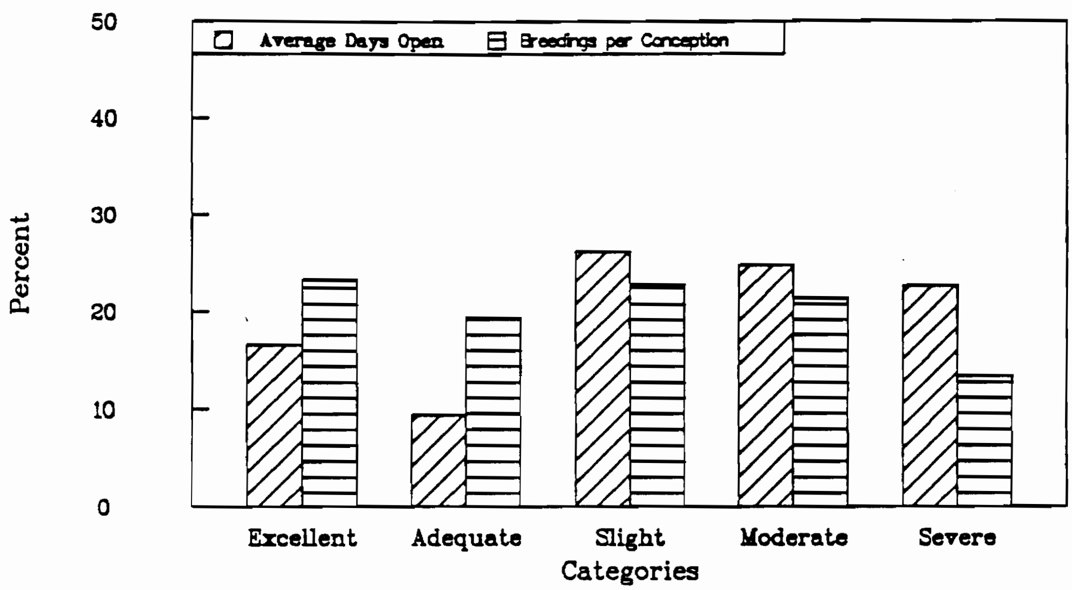


Figure 8. Percentage of 792 Virginia DHIA herds categorized by days open and breedings per conception.

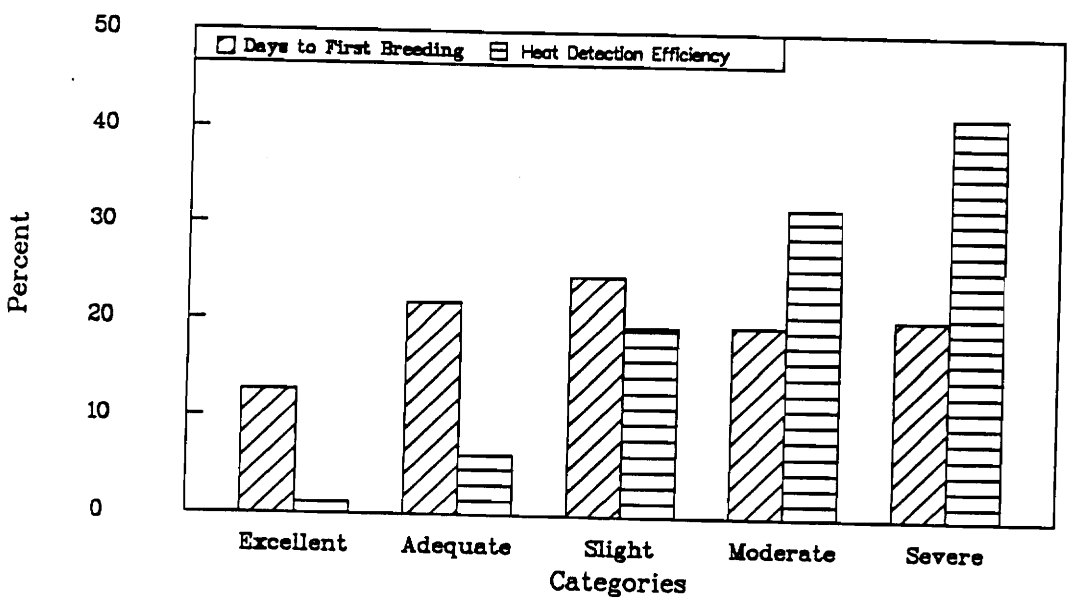


Figure 9. Percentage of 792 Virginia DHIA herds categorized by days to first breeding and efficiency of detection of estrus.

Herd averages for each of the four reproductive parameters are entered into the ES and interpretations are displayed along with herd averages and goals. The ES then makes a recommendation to evaluate the area in most need of attention by comparing the interpretation levels of DFB, CR, and ED. If all areas are "excellent" or "adequate'" the ES determines that a problem does not exist. When interpretations are identical for the three areas, the ES will evaluate the CR area because recommendations regarding CR are generally easier to implement and will show more immediate results than correction of the other two areas. If CR subsequently improves due to the recommendations of the ES, the other problem areas can be investigated and recommendations will more likely be implemented due to past success. When ED and DFB are the lowest rated areas, the ES will evaluate ED because detection of estrus has a large effect on DFB. Regardless of the problem selected by the program, the user can select any area for evaluation.

If ED is "severe," the ES calculates a new ED because the ED provided through DHIA is based on voluntary waiting period and may not accurately indicate the number of estruses observed on the farm. The period from parturition to first insemination is the voluntary waiting period (VWP). In DHIA it is often defaulted to 60 d. The ES asks how many days the average cow is in milk before insemination, and uses this figure as the herd's actual VWP. A regression developed from combinations of theoretical DFB and voluntary waiting periods is used to predict a new ED based on the herd's voluntary waiting period and DFB. Using this VWP, an equation was developed to predict DFB from estrous detection percentage (p) through N potential estrous cycles.

$$DFB = \sum_{n=1}^{N} [(VWP + 10) + 21(n - 1)]p(1 - p)^{n-1} \qquad [1]$$

Multiplying by 1-p and subtracting reduces this summation to

$$DFB = (VWP + 10)[1 - (1 - p)^{N}] + 21[(1 - p) - N(1 - p)^{N}(N - 1)(1 - p)^{N+1}]/p \qquad [2]$$

A data set of DFB was generated from a variety of VWP's and p's. Percentage of estrus detection was regressed on DFB to yield a new ED, equation [3], which will often be more accurate than the DHI value based on an inaccurate VWP.

$$ED = 93.3 - 2.44152(DFB - VWP - 10) + .0210172(DFB - VWP - 10)^2 \quad [3]$$

Equation [3] had an r^2 of .979. The linear SE was .1538, whereas the quadratic SE was .0024. At 58 d beyond the VWP, ED efficiency reaches a minimum value of 25% and then begins to rise slightly. This rise is due to extended DFB and the limit of seven services in equation [2], where cows never seen in heat begin to be lost from the DFB average because of culling. For equation [3] to be an accurate predicator of ED, all observed estruses have to be recorded, even if no insemination takes place. Natural service herds are a problem because estruses are not observed and recorded. The VWP must also be an accurate reflection of farm practices.

Evaluation of Conception

The general organization and flow of the CR evaluation is in Figure 3. The ES investigates cow infertility by evaluating reproductive reports available through the DART system developed by the Dairy Records Processing Center in Raleigh, NC. These reports, available for all herds in DHI, are used in the daily management of the farm, but can also be captured in an ASCII file. The ES reads and interprets seven reports according to criteria established by the extension specialist. Reports include conception rate categorized by parity, service number, days in milk, service sire, breed and projected mature equivalent production. For example, the report of conception rate by parity is used to evaluate differences in CR due to age of cow. If a difference in CR exceeds 15% between first lactation and combined second and third lactations, reasons are suggested for the discrepancy and recommendations are given. If no problems can be related to the CR portion of the ES, it hypothesizes that sire fertility, semen handling, or AI technique may be responsible for the low herd CR, and these are evaluated.

To determine if service sires may be responsible for a low CR, the ES uses the report of conception rate by service sire to determine how many service sires with an Estimated Relative Conception Rate (ERCR) below -3 are being used by the farm. The ERCR is calculated by DHIA for AI services over a 3 yr period. The average sire has an ERCR of 0. Sires with more than 20 services and a CR below 25% in the herd are also identified and recommended for limited use. If natural service is used, the ES evaluates management practices to determine if natural service is lowering CR.

Conception rate for the herd for the most recent 6 mo is compared to Virginia monthly averages of the past 3 yr. A linear regression of CR on 6 mo is calculated for the herd. The herd slope and predicted average at 3 mo are compared with the state slope and average corresponding to the same month. The slope smooths and accounts for seasonal trend in CR, and permits statistical comparison by t-test. Herds below state average or trend ($P < .20$) are identified as having seasonal CR problems for which appropriate recommendations are provided.

Evaluation by the ES of factors influencing CR concludes by investigating the accuracy of detection of estrus, semen handling, and AI technique. Examples of questions asked in this portion of the ES include prostaglandin use, how semen is thawed, where semen is deposited, and whether horn breeding is used. All management questions are yes/no or multiple choice. Where appropriate, the ES gives suggestions on how to correct problems.

Evaluation of Detection of Estrus

When efficiency of detection of estrus is designated as a problem, further analysis requires information regarding estrous interval lengths printed by DHIA and manually entered by the user. In addition the ES requires the percentage of cows first serviced after 100 d in milk. The extension reproductive specialist sets acceptable levels for each question asked. The ES determines whether estruses are missed because of a poor observation routine or whether signs of estrus are not recognized.

The computerized DART reproductive report by milk yield is used to determine if milk yield is interfering with detection of estrus. If a 12 d difference is found between the estrous intervals of high (110% of average) and low (80% of average) producing cows, recommendations are given on how to improve detection of estrus in high producers. For example, more time needs to be spent observing high producing cows and the effects of negative energy balance should be reduced.

The ES questions whether the farm has a routine estrus detection program. If not, the system recommends and describes a typical program. The ES then asks the length of estrus observation periods, where cows are observed for estrus and which individuals are checking for estruses. The ES describes how improvements can be made. A list of signs of estrus is generated, and for each sign not selected, the ES describes why the oberver should be alert to that sign. The evaluation of detection of estrus concludes by re-emphasizing the importance of routine daily observation of estrus and reviewing signs of estrus.

Evaluation of Days to First Breeding

The DFB evaluation is the smallest component of the ES as it is selected only when other areas are satisfactory. The ES investigates factors associated with the herd's voluntary waiting period. The effects of milk production on DFB are evaluated using the computerized DART production report. If higher producing cows have a DFB 12 d or more greater than lower producing herdmates, a problem exists and the ES gives suggestions on how to improve the situation. The importance of detection of estrus is also described. The ES investigates cow health by asking questions regarding parturition problems such as milk fever, dystocia, retained placenta, and components of the herd health program.

Program Validation

Ten Virginia DHIA herds with poor conception rates (Greater than 2.5 breedings per conception) were selected for evaluation. Characteristics of the herds are listed in Table 4. Herds averaged 142 cows, 9017 kg of milk with 138 d open and 39% CR. The DART reports were captured in files for the ES, and a chart was developed listing all areas evaluated using the DART reports. The extension specialist interpreted the DART reports and identified problem areas. The ES evaluated the same reports and, where problems were identified, the chart was marked by the program user.

Table 5 lists ten areas which were evaluated for each herd. The ES and extension specialist identified 47 problem areas across the ten herds, agreeing on 40 areas, or 85%. The extension specialist found six problem areas that the ES failed to find, while the program identified one area not selected by the extension specialist. Only the extension specialist determined that CR varied by days in milk in herd 1. The CR for inseminations at less than than 100 d in milk was 31%, while CR for over 100 d was 41%. Only a difference greater than 15% is identified by the ES. Herd 2 was identified by the extension specialist as having a CR problem due to factors associated with lactation number and AI service number. In both instances a 14% difference in CR was identified by the expert as a problem, whereas the ES required 15%. The ES and extension specialist also disagreed on the identification of low CR service sires. The program identifies sires with at least 20 inseminations and a CR below 25%. The extension specialist determined that three herds had low CR sires even though the lowest CR reported for any sire was 30%. The extension specialist declared higher CR to be a problem if the number of services was larger, such as 30% CR for 82 services. The one herd identified by the ES for using low CR sires was missed by the expert.

Table 4. Characteristics of ten Virginia DHIA herds used for validation of the expert system.

Variable	HERD 1	2	3	4	5	6	7	8	9	10	Mean	SD
No. cows	101	86	102	328	191	172	174	200	82	186	142	64
ME milk, kg	8948	9006	8945	10768	9800	9432	7997	7481	8519	9276	9017	918
Fat, %	3.4	3.8	3.5	3.6	3.4	3.3	3.6	3.4	3.5	3.4	3.5	.15
Days open	162	142	126	127	119	118	159	123	151	149	138	17
Days to First service	84	80	77	87	63	74	94	73	81	91	72	27
Conception, %	33	37	39	36	28	32	39	36	29	36	38	5
Estruses observed, %	47	43	52	55	68	64	42	50	41	54	51	9
Estrous interval	46	60	37	36	35	35	51	40	57	40	43	9
Yearly reproductive Culling, %	3	7	5	5	9	12	10	7	9	11	7.8	2.9

Table 5. Comparison of program and expert identification of reproductive problems for ten Virginia DHIA herds use for validation of

				DHI Rating Report						
	LN	SN	DIM	DO	DFB	B/C	HIN	ERCR	LCB	NB
Herd 1		*	E	*		*	*			*
Herd 2	E	*	*	*						*
Herd 3								*	E	*
Herd 4	*			*	*	*		*	E	*
Herd 5		*		*		*			P	*
Herd 6				*		*				*
Herd 7		*	*	*		*				*
Herd 8		E							E	*
Herd 9			*	*		*		*		*
Herd 10				*		*	*	*		*

* = Program and Expert identified problem
P = Program only
E = Expert only

LN = Lactation Number
SN = Service Number
DIM = Days in Milk
DO = Days Open by DHI rating
DFB = Days to First Breeding by DHI rating
B/C = Breedings per conception by DHI rating
HIN = Heat Interval by DHI rating
ERCR = Estimated Relative Conception Rate below -3
LCB = Low Conception Rate Bulls
NB = Number of bulls used

The extension specialist determined that the ES was identifying problems correctly and no major changes were made in the ES. However, it may be reasonable to increase minimum thresholds used to identify problems according to a formula which accounts for increases in information such as more breedings.

A questionnaire was developed to be used by extension personnel to obtain during farm visits and interviews information needed by the ES. The questionnaire was shown to five dairy farmers who made suggestions for improvement. Most changes had to do with the wording of questions where farmers wanted easier interpretation. The revised questionnaire is in Appendix D.

Conclusions

Program Delivery

The ES is an executable file that calls five compiled knowledge bases. In addition, there are two ASCII files, one containing monthly CR for the state of Virginia and the other a list of active AI sires and their ERCR values. All files needed to run the ES can be delivered on one 360K, 5.25″ floppy disk for IBM compatible microcomputers with 512K RAM. The DART reports needed by the ES should be captured on a floppy disk before the evaluation begins. A DHI herd code and the DRPC communication program are required. Capturing the DART reports takes approximately 5 min per herd. Once all information has been assembled, the ES takes about 10 min to run.

Program Development Problems

Expert systems are a fairly recent technology in both software and computing equipment. Because of this, development of the ES was an involved learning process. Two shell programs were used learn the capabilities of expert systems. The PCX Professional shell was selected over Level 5 for program development due to the flexibility and ease in which Turbo Pascal 5 could be used to enhance program capabilities. In addition, no ES compiler or run-time module was needed, which eliminated the need for program users to buy additional programs to run the ES. The PCX Pro shell is a recently developed shell program and does have some problems. In an effort to make the shell simple to use, it contains a menu interface which will hinder some advanced programmers. Elimination of the menu would reduce key strokes and confusion as to key assignments depending on what section of the menu is being used. The manual is not easy to understand and some of the commands used for Turbo Pascal interaction are not clear or do not operate as the manual describes. Despite these problems, this shell worked well for development and can be used in future programs.

The ES was to be designed to be used by extension personnel. Although dairy farmers would benefit from actually seeing it run, and may be more likely to implement recommendations under that circumstance, most farmers do not have the computer hardware and expertise needed to run the program. Extension agents can use the questionnaire to gather information at the farm, return to the office, download by computer the needed DART information and run the ES. Recommendations and suggestions from the program can be printed and returned to the farmer. An effort was made to make the program simple to use. Keystrokes were eliminated by using yes/no and multiple choice questions.

Several methods of obtaining and using data were considered. Originally all reproductive performance data were to be entered in the ES from the keyboard. The DHIA 202 report does not exist in a form that allows a direct download into the ES. These data have to be entered from the keyboard. Data from the DART reports can be read by the ES because the reports can be captured as ASCII files. The use of pascal allows for the reading of captured DART reports. The shell program does not have the capability to read the DART information. Because the ES can read DART reports, data entry and evaluation time is reduced. However, only DHIA herds that have records processed in Raleigh can be evaluated by the ES. A questionnaire was necessary to guide the collection of non-DHIA management information needed by the ES.

Reproductive management was divided into three areas (DFB, CR, and ED) for evaluation by the ES. Although the three areas are considered mutually exclusive by the ES, it is important to remember that each area is biologically related and influences the others. However, by identifying one problem area for evaluation, and giving recommendations and suggestions for improvement, it is assumed that other areas will also improve. A concentrated effort to improve the specific area identified should be superior to using a broader approach to solve all reproductive problems at once.

The initial reproductive analysis of DO, DFB, CR, and ED identifies the area that needs to be further evaluated. Interpretation levels were established by the extension reproductive specialist. Because of the predominance of the Holstein, interpretation levels were established for Holstein herds. A slight adjustment may be needed for evaluation of other breeds. For example, Jersey herds may require higher reproductive goals than Holsteins, so interpretation levels will have to be adjusted. When all areas were interpreted to have equivalent difficulties, conception rate problems were selected because they represent techniques which are usually easier to correct than ED or DFB, where improvements may require strategic, psychological or even pathological changes of the farmer. An improvement in CR is also more immediate. Because the ES will select the CR evaluation often, an option is given to the user to evaluate other areas. It may be desirable in the future to determine how many herds are evaluated in each of the three areas and adjust the method by which the ES selects the area for evaluation. According to recent DHIA information from 792 Virginia herds, over 41% would be rated as having a "severe" problem with detection of estrus according to interpretation levels set by the extension specialist. A regression equation was developed to adjust the ED efficiency of herds based on VWP and DFB. The number of herds adjusted to higher interpretations should be monitored to determine if the adjustment is necessary. The ES may need to be changed so that an evaluation of detection of estrus is more frequent.

The problem solving capabilities of the ES seem to be similar to those of the extension specialist. Recommendations and suggestions closely matched. However, the extension specialist has an advantage for two reasons. The ES will only recognize a problem after a fixed threshold is reached. The specialist uses more latitude in identifying problems. Whereas a 15% difference may be needed before the ES identifies a problem, the specialist may determine problems at 14% based on other numbers involved in the calculation. However, the ES more than the extension specialist should be consistent in problem identification. Secondly, the extension specialist is better able to condense recommendations and suggestions to farmers. The ES identifies problems well, but does not eliminate duplicate recommendations and suggestions. A method is needed for relating recommendations and suggestions to give a more concise recommendation for the problems identified. It may be necessary to prioritize problems recognized by the ES so that the number of recommendations is reduced, or keep extensive track of all prior recommendations to reduce duplication.

The ES can only evaluate DHIA herds that send data to the DRPC in Raleigh, NC because of the DART reports needed for the evaluation. However, dairy producers in 14 states and Puerto Rico send information to Raleigh. There are several ways in which the program could be used in other parts of the country. It could be enhanced so that it is capable of reading reproductive reports produced by the other eight DRPC. Otherwise, all data needed could be entered from the keyboard.

Because the ES is dependent on the DART reports created by the DRPC in Raleigh, a close working relationship needs to be maintained between the ES developers and the DRPC. When the DRPC changes a DART report, the ES will need to be adjusted also. The recommendations of the ES developers should also be considered by the DRPC. Needs for the immediate future include capturing the DHI 202 report as a DART report. The DHI rating report should be changed to report a decimal place for breedings per conception. In the future, it may be possible to include ES recommendations and suggestions in the mail-in DHI program. By doing this, DHI will be capable of providing both strategy and tactics for improved management.

For the ES to be effective, accurate information has to be obtained from DHI. The dairy farmer should report all information to DHI. For example, the ES has to verify ED because the VWP reported to DHI may not be correct. The importance of reporting the VWP needs to be explained. One possible solution to the VWP problem is to eliminate the 60 d default used by DHI, and require every dairy farmer to report a VWP. It is important to remember that the recommendations of the ES are limited by the accuracy of data entered into the ES.

It is difficult to compare this ES to other expert systems in dairy management. There has been much discussion about expert systems for dairy management, but few programs exist. Any comparison would involve some speculation. Programs seem to exist at Maryland, West Virginia, and possibly Minnesota, but there is limited published information on them. An ES for reproductive management has been developed by Cornell. However, the Cornell ES runs on a mainframe computer and therefore appears to have limited practical benefit to dairy farmers at this time. It appears that most ES have not been validated by field use and have not been the focus of publications.

Before the ES is changed further, the program should be used in field situations. Extension area dairy specialists, along with the state extension specialist should use the program. If it is useful for identification of reproductive problems, then changes will enhance the program. If the program is not used by extension, then the ES may need to be reviewed to determine why the program was of little value.

Project Overview

Several problems slowed this project. Much time had to be spent learning the basics of expert systems. Prior computer programming experience would have made communication between the graduate student and department computer programmer more efficient, especially at the beginning of the project. The department programmer spent time explaining the basics of Pascal programming instead of working on more advanced techniques that possibly could have been used in the program. A course in Pascal programming would have been helpful in enhancing the development of the program. Future developers of expert systems should have courses in expert systems and, if necessary, computer programming. Because the extension specialist was articulate and interested in developing an ES, obtaining information was not difficult. According to other ES developers, the largest problem in developing an ES is obtaining accurate information and expertise. Despite the project difficulties, the ES should aid extension personnel to identify dairy herd reproductive problems and give recommendations on how to correct problems.

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Appendix A. Computer Software

Appendix A.Computer software used for program development.

Turbo Pascal 5
Borland International
1800 Green Hills Road
P.O. Box 66001
Scotts Valley, CA 95066-0001

PC Expert Professional
Software Artistry, Inc.
3500 DePauw Blvd. Suite 2021
Indianapolis, IN 46268

Appendix B. Download Procedures

```
Appendix B. Download procedures for capturing DART files

ENTER 1-DIGIT APPLICATION CODE -- OR L TO LIST AVAILABLE APPLICATIONS
? 11

ENTER HERDCODE
? 52xxxxxx

ENTER PROCEDURE P0..P10, REPORT NUMBER, --OR L TO LIST PROCEDURES,
  0 TO CHANGE REF DATE FROM 051190
? P0

ENTER REPORT NUMBER -- OR L TO LIST REPORTS
? 2
```

Appendix C. DART Reports

```
RPT #02    HERD: 52xxxxxx    REF DATE: 070790                          PAGE: 1
REPRODUCTION REPORT BY DHI RATING

MAJ        MIN
R          L CURR  PROJ  CUR      OPN R  B  SRVC SIRE SRV
A          A T.D.   ME   TD DAYS FST E  R    NAME OR HEA
T   INDEX  C  FCM  MILK  PRO OPEN BRD P  #  NAAB CODE INT
*      12 COW AVERAGE FOR MINOR GROUP 01 (MIN:          1 MAX:          1)
B          1   49  21017 3.4  170  81    2                59
*       6 COW AVERAGE FOR MINOR GROUP 02 (MIN:          2 MAX:          2)
B          2   48  22557 3.3  168  92    3                45
*      20 COW AVERAGE FOR MINOR GROUP 03 (MIN:          3 MAX:          9)
B          4   52  23085 3.2  229  92    3                58
***    38 COW AVERAGE FOR MAJOR GROUP 01 (MIN: A          MAX: B        ) *
B          3   50  22349 3.3  201  88    3                56
*       7 COW AVERAGE FOR MINOR GROUP 01 (MIN:          1 MAX:          1)
C          1   49  18859 3.1  125  73    3                31
*       4 COW AVERAGE FOR MINOR GROUP 02 (MIN:          2 MAX:          2)
C          2   49  19263 3.3  154  86    4                24
*      13 COW AVERAGE FOR MINOR GROUP 03 (MIN:          3 MAX:          9)
C          4   63  18866 3.0  134  90    2                47
***    24 COW AVERAGE FOR MAJOR GROUP 02 (MIN: C          MAX: C        ) *
C          3   57  18930 3.1  135  84    2                36
*       9 COW AVERAGE FOR MINOR GROUP 01 (MIN:          1 MAX:          1)
D          1   39  15910 3.0  144  69    3                37
*       7 COW AVERAGE FOR MINOR GROUP 02 (MIN:          2 MAX:          2)
D          2   44  17052 3.0  137  71    3                38
*      10 COW AVERAGE FOR MINOR GROUP 03 (MIN:          3 MAX:          9)
D          5   46  16633 3.3  121  90    2                36
***    26 COW AVERAGE FOR MAJOR GROUP 03 (MIN: D          MAX: E        ) *
D          3   43  16495 3.1  133  77    2                37
****   88 COW AVERAGE FOR GRAND TOTALS                                    **
C          3   50  19687 3.2  163  84    3                46
ENTER PROCEDURE P0..P10, REPORT NUMBER, --OR L TO LIST PROCEDURES,
  0 TO CHANGE REF DATE FROM 070790P10
```

CONCEPTION RATE BY SERVICE SIRE FOR SERVICES
DURING THE PERIOD 10-15-89 TO 05-03-90

LAST DATE OF TEST = 07-07-90

***** SERVICES BY MONTH FOR LAST SIX COMPLETE MONTHS IN THIS PERIOD *****

		TOTAL FOR PERIOD			** 11-89 **		** 12-89 **		** 01-90 **		** 02-90 **		** 03-90 **		** 04-90 **	
SIRE REG. #	SIRE CODE # OR NAME	# SERV.	# SUCC.	% SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC
1590154	AMOS	1	1	100	1	1										
1590582	WAYNE(MF)	1	0	0			1									
1608425	CINNAMON	1	1	100			1	1								
1697281	STARFIRE	1	0	0			1									
1765326	MEMORIAL	26	10	38	3		1	1	2		4	2	1		12	6
1810969	MANDINGO	18	7	38	1		2	1	6	1	2	1	6	3		
1818972	MELVIN	13	7	53	1		3	1	3	2	2	2	1		2	2
1836624	COMMAND	16	4	25	1		2	1	4		4	2	1		4	1
1840808	CALYPSO	3	1	33												
1844813	SELECTION	1	1	100												
1878472	PONTIAC	20	7	35	5	1	1		2		5	3	3	1	2	1
1884404	PETE TIDY	12	3	25	1	1			1	1	6	1	3			
1890669	JAYBOY	8	2	25			1	1			1				3	
1896502	REAGAN	9	3	33	5	1	1	1	1	1			1		1	
1935264	MICHEAL	11	7	63	1	1	1	1	1	1	1		3	1	4	3

CONCEPTION RATE BY SERVICE NUMBER FOR SERVICES
DURING THE PERIOD 10-15-89 TO 05-03-90

LAST DATE OF TEST = 07-07-90

***** SERVICES BY MONTH FOR LAST SIX COMPLETE MONTHS IN THIS PERIOD *****

	TOTAL FOR PERIOD			** 11-89 **		** 12-89 **		** 01-90 **		** 02-90 **		** 03-90 **		** 04-90 **	
SERVICE NUMBER	# SERV.	# SUCC.	% SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC
1	47	14	29	5		7	1	7	2	10	4	6	2	10	4
2	33	15	45	2	1	3	2	5	1	8	4	4	1	7	4
3	23	6	26	5	1			4	1	4	1	3		3	1
4	16	9	56	3	1	1	1	1		3	2	2	1	5	3
5+	22	10	45	4	2	4	4	3	2			4	1	3	1

CONCEPTION RATE BY LACTATION NUMBER FOR SERVICES
DURING THE PERIOD 10-15-89 TO 05-03-90

LAST DATE OF TEST = 07-07-90

***** SERVICES BY MONTH FOR LAST SIX COMPLETE MONTHS IN THIS PERIOD *****

	TOTAL FOR PERIOD			** 11-89 **		** 12-89 **		** 01-90 **		** 02-90 **		** 03-90 **		** 04-90 **	
LACTATION	# SERV.	# SUCC.	% SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.
1	48	18	37	7	3	8	3	8	1	10	4	6	2	5	3
2	31	13	41	4	1	3	2	5	3	5	2	3		6	3
3	19	6	31	2		4	3	2				3	1	7	2
4	21	10	47	2	1			1	1	6	1	5	2	5	4
5+	22	7	31	4				4	1	4	4	2		5	1

CONCEPTION RATE BY DAYS IN MILK FOR SERVICES
DURING THE PERIOD 10-15-89 TO 05-03-90

LAST DATE OF TEST = 07-07-90

***** SERVICES BY MONTH FOR LAST SIX COMPLETE MONTHS IN THIS PERIOD *****

	TOTAL FOR PERIOD			** 11-89 **		** 12-89 **		** 01-90 **		** 02-90 **		** 03-90 **		** 04-90 **	
DAYS IN MILK	# SERV.	# SUCC.	% SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.
< 050	1	0	0												
050-059	4	1	25			1						1		1	
060-069	11	2	18	1		3	1	2				2	1	3	
070-079	8	3	37	1		1		2	1	1	1	1		1	1
080-089	10	3	30			1		2		5	2			1	
090-099	10	5	50	2	1			3	1	3	1			2	2
100-119	16	3	18	3		2	1	1		3		2	1	4	1
120-149	19	9	47	4	1	1	1	1	1	5	2	4		1	1
150 +	62	28	45	8	3	6	5	9	3	8	5	9	3	15	8

CONCEPTION RATE BY BREED OF COW FOR SERVICES
DURING THE PERIOD 10-15-89 TO 05-03-90

LAST DATE OF TEST = 07-07-90

	TOTAL FOR PERIOD			***** SERVICES BY MONTH FOR LAST SIX COMPLETE MONTHS IN THIS PERIOD *****											
				** 11-89 **		** 12-89 **		** 01-90 **		** 02-90 **		** 03-90 **		** 04-90 **	
BREED OF COW	# SERV.	# SUCC.	% SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	# SERV.	# SUCC.	SERV.	# SUCC.	# SERV.	## SUCC.
H	141	54	38	19	5	15	8	20	6	25	11	19	5	28	13

Appendix D. Questionnaire

Appendix D. Questionnaire used to obtain herd reproductive performance and management information.

Farm Name:______________________ Herd Code__________ Date________

A. DHI Data

1. Average Days Open ________
2. Average Days To First Breeding ________
3. Breedings per Conception ________
4. Percent of Possible Heats Observed ________
5. Are all observed heats recorded? (Y/N) ________
6. Is natural service used on the farm? (Y/N) ________
7. How many days after calving does insemination begin for the average cow? ________
8. How long is the herd's voluntary waiting period? ________
9. What percent of all first services are before the end of the voluntary waiting period? ________

B. Herd Health

10. What percent of the herd had a metabolic disorder at calving? (circle appropriate answer)

    less than 5%   5 to 10%   greater than 10%

11. What percent of the herd needed assistance with calving?

    less than 5%   5 to 10%   greater than 10%

12. What percent of the herd had a retained placenta?

    less than 5%   5 to 10%   greater than 10%

13. Is the herd on a regular herd health program? (Y/N)____

If yes, select all examinations that are a part of the health program.

Post calving examination

30 day postpartum examination

45 day pregnancy check

Cows with no "heats" are examined

Problem cows are examined

14. Have all reproductive culls been reported to DHI? (Y/N)____

C. Heat Detection

15. Does this farm have a routine heat detection program? (Y/N)____

16. How many times per day are cows checked for heats?

Once   Twice   More than twice

17. How many minutes long are heat detection observation periods?

Less than 15 minutes   15 minutes   More than 15 minutes

18. What are cows standing on during the observation periods?

Concrete   Dirt   Both   Neither

19. Has the person who is observing heats been trained in heat detection? (Y/N) ______

20. Please circle all signs of heat used on the farm

Standing heat

Mounting other animals

Bawling

Restless and nervous

Vaginal discharge

Reduced milk yield

Off feed

21. Are heat detection aids used on the farm? (Y/N) _____

22. Are heat mount detectors used on the farm? (Y/N) _____

23. Are milk progesterone tests being used on the farm? (Y/N)_____

24. Is chalking and tail painting being used? (Y/N) _____

25. How many heat intervals between 18 and 24 days? _____

26. How many heat intervals between 36 and 48 days? _____

27. How many "other" intervals? _____

28. What percentage of cows are first serviced after 100 days?____

29. Are all pregnancies being recorded prior to 60 days after insemination? (Y/N) _____

30. Are heat detection expectancy lists being used? (Y/N) _____

31. Are cows moved to a special location for heat observation or just prior to heat observation? (Y/N) _____

32. Are at least two observation periods 12 hours apart? (Y/N)_____

33. Circle all areas where cows are observed for heat.

Free stalls

Feed bunks

Dirt lot

Milking parlor

Holding pen

Pasture

Other

D. Natural Service

34. Is more than 25% of the herd bred naturally? (Y/N) _____

(If yes, then answer questions 35 to 40)

35. Are bulls with cows all of the time? (Y/N) _____

36. Has the bull been observed mounting different cows? (Y/N)_____

37. Has the bull had a reproductive soundness examination?(Y/N)____

38. Has the bull been checked for disease? (Y/N) _____

39. What is the general condition of the bull?

Good Fair Poor Over-Conditioned

40. What is the most number of cows running with each bull? _____

E. A.I. Procedures

41. How many cows in the herd? _____

42. Is Lutalyse being used in the herd? (Y/N) _____

43. Are cows being inseminated according to veterinary palpation recommendations? (Y/N) _____

44. When are cows inseminated in relationship to standing heat? (Circle the appropriate answer)

Less than 12 hours 12 hours Greater than 12 hours

45. Does the herd have a different breeding policy for third service? (Y/N) _____

46. Is Cystoarelin (GnRH) used for third service? (Y/N) _____

47. Are more young sires used for third service? (Y/N) ____

48. Is natural service used on more than 50% of third services? (Y/N) _____

49. Circle all people who inseminate cows on the farm.

Owner

Herdsman

Farm employee

AI technician

50. Is 80% or more of the herd bred by an AI technician? (Y/N) _____

(If yes, no further questions need to answered)

51. How many different people inseminate cows on this farm? _____

52. Is semen removed from the semen tank within 10 seconds? _____

53. Is the cane of semen kept below the frost line during straw removal? (Y/N) _____

54. How are straws removed from the semen tank?

Fingers   Tweezers   Split sheath

55. How is semen thawed?

Water   Air(pocket thaw)   In breeding gun

56. What is the temperature of the water semen is thawed in?

85 to 90F   90 to 95F   95 to 100F   Greater than 100F

57. Has the water bath thermometer been checked in the last 6 months? (Y/N) ____

58. Has the water bath been cleaned in the last month? (Y/N) ____

59. How long is semen thawed in the water bath?

Less than 30 seconds   30 to 60 seconds   Greater than 60 seconds

60. Is the AI rod and sheath warmed before the straw is loaded? (Y/N) ____

61. Is the AI straw dried off before placed in the breeding gun? (Y/N) ____

62. Is a paper towel placed around the tip of the AI rod? (Y/N) ____

63. Is the tip of the AI straw cut on a 90 degree angle? (Y/N) ____

64. Is there a good seal between the straw and AI sheath? (Y/N) ____

65. Is the plunger pushed to the cotton plug? (Y/N) ____

66. Is the loaded AI gun kept warm and protected from the environment? (Y/N) ____

67. How long after thawing is the cow inseminated?

Less than 5 minutes   Less than 10 minutes   More than 10 minutes

68. Is the semen tank maintained and filled as needed? (Y/N) ____

69. Is the vulva wiped off before the AI rod is inserted? (Y/N) ____

70. Is the AI rod inserted at a 30 degree angle from the cow's topline? (Y/N) ____

71. Circle all sites of semen deposition used on the farm.

Vagina

Cervix

Uterine body

One uterine horn

Both uterine horns

Unknown

72. How fast is semen deposited once the AI rod is at the deposition point?

Less than 3 seconds   Greater than 3 seconds

73. Have inseminators been trained to horn breed? (Y/N) ____

74. Is the AI rod cleaned & stored after each insemination?(Y/N)____

Vita

Name:	Joseph J. Domecq
Birthplace:	Whittier, California January 22, 1964
High School Education:	Monache High School Porterville, California 1978-82
College Education:	California Polytechnic State University San Luis Obispo, 1988 Bachelor of Science in Dairy Science and minor in Agricultural Production Management, 1988.
Honorary Organizations:	Alpha Zeta
Professional Organizations:	American Dairy Science Association

Abstracts:

Domecq, J. J., R. L. Nebel, and M. L. McGilliard. 1989. An expert system to evaluate reproductive management and the need and selection of an on-farm milk progesterone test. J. Dairy Sci. 72 (Suppl. 1):460.

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Joseph J. Domecq