# GENETIC CONSIDERATIONS FOR RAISING REPLACEMENT HEIFERS

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Dairymen are constantly concerned with the improvement of their herds. Dairy cattle improvement is most frequently expressed as increased milk production though sometimes in terms of changes in body conformation. Data in Table 1 illustrate the relationship between level of production and potential profit.

Table 1: FLORIDA 1974-75 DHI DATA
GROUPED ACCORDING TO MILK PRODUCTION PER COW

| Milk Pounds | % Fat | Lbs Fat | Value of Product | Feed Cost | Income Over Feed Cost | Feed Cost Per Cwt Milk Dollar |
|---|---|---|---|---|---|---|
| 15957 | 3.6 | 569 | $1703 | $792 | $911 | $4.96 |
| 13460 | 3.6 | 482 | 1481 | 671 | 810 | 4.98 |
| 12330 | 3.4 | 425 | 1343 | 659 | 684 | 5.35 |
| 11391 | 3.5 | 398 | 1245 | 632 | 613 | 5.55 |
| 10581 | 3.7 | 391 | 1169 | 591 | 578 | 5.59 |
| 9633 | 3.8 | 363 | 1074 | 580 | 494 | 6.02 |
| 8150 | 4.4 | 356 | 946 | 464 | 482 | 5.69 |
| State Average | | | | | | |
| 11431 | 3.6 | 410 | 1257 | 622 | 635 | 5.44 |

Both environment and genetics contribute to variation in milk production. Environment is usually considered in terms of feeding, disease control, reproduction and milking practices. Genetics refers to a cow's inherited ability. Greater milk production can result from intelligent management of environmental or genetic factors. This paper presents information relative to understanding, interpreting and using performance data for genetic improvement of dairy cattle.

The genetic ability of a herd can be improved only by addition of new animals that are superior to the ones being replaced. Thus two processes are involved; old cows leaving the herd and new cows entering.

Some of the cows sold are genetically good but must be removed because of infertility, disease, injury or other reasons. Other cows are *chosen* to be sold because they are poor producers. To maximize genetic progress, one must be able to make as many of the culling decisions as possible based on true genetic differences in producing ability. Data in Table 2 illustrate the difference in production level between cows sold from Florida DHI herds for low production and cows sold for other reasons.

Table 2 on next page

Table 2
COMPARISON OF HERDMATE DIFFERENCE (HMD) MILK PRODUCTION FOR FLORIDA DHI COWS SOLD FOR LOW PRODUCTION VS OTHER

| | | | Cows Left Herd For: | | | |
|---|---|---|---|---|---|---|
| | | | Low Production | | Other Reasons | |
| Breed | Cows Per Herd | 305-2X ME Milk | No. Cows | HMD Milk | No. Cows | HMD Milk |
| Guernsey | 360 | 9772 | 36 | - 512 | 93 | + 82 |
| Holstein | 276 | 13617 | 26 | -1136 | 38 | -176 |
| Jersey | 235 | 9043 | 20 | - 901 | 67 | -147 |
| Brown Swiss | 173 | 12728 | 35 | -1278 | 19 | -181 |

October, 1975 ERPA Run

The levels of production are expressed as deviations from herdmates. It can be seen that the cows sold for low production were more highly negative than cows sold for other reasons. This indicates that the cows sold for reasons other than low production were much better cows than were those sold for low production. So we see that environmental management and genetic management are related. Herds that have good management of environment, e.g. feeding, disease control, heat detection, good cow identification, etc. have more opportunity to cull for *inferior genetic ability* (low production). In other words,

PERFORMANCE = ABILITY + OPPORTUNITY

where ability is defined as the heredity and opportunity is defined as the environment permitting expression of the inherited capacity for milk production.

Some dairies rely totally on purchased replacements while some raise their own and still others use both sources. Whichever method is used, dairymen should be conscious of the genetic ability of new cows entering the herd so that an evaluation can be made.

Any dairymen who buys replacements should obtain as much information as possible about the quality of the cattle in order to make good purchasing decisions. Useful information includes: origin of animals (both immediate and original), information on the herd of origin, sires, dams' production, comments from others who have purchased from the source in question and others. There are certain legal requirements regarding health and certainly the more information obtained, the better chance for a successful purchase.

Home-raised replacements offer the greatest opportunity to maximize genetic progress economically. Good cattle are available for sale but the price may be high. Florida dairymen have access to the same sires through artificial insemination (AI) as do the breeders who sell cattle. By intelligent selection of sires the genetic ability of the resulting heifer calves can be improved considerably. Feed and management costs for raising replacements are the same regardless of genetic ability, so greater net returns can be expected from the genetically superior, home-raised replacement heifers.

Some basic genetic principles should be helpful in developing a genetic management program. One is the concept of *heritability*. Heritability is a measure of the degree to which a trait, such as milk yield, is genetically determined. A zero heritability would mean that no genetic change could be expected from usual selection techniques; whereas, a trait with 50% heritability could be selected for quite effectively. A good practical definition of heritability can be stated as the fraction of merit (or lack of merit) observed in the parents which is transmitted to the offspring with merit being described as a deviation from the population average. For example, the heritabilities of several traits in dairy cattle are: milk yield, 25%; fat percentage, 55%; birth weight, 40%; mature weight, 50%; wither height, 50%; overall type score, 20%. Traits which are heritable presumably can be changed by selection, but the degree of heritability determines the rate at which that progress can be obtained.

*Variability* is another concept which must be considered in understanding the science of genetics. Table 3 illustrates the normal variation found in milk production records from 59 daughters of one particular bull.

Table 3
NORMAL DISTRIBUTION OF BULL'S DAUGHTERS
AVERAGING 14842 POUNDS MILK

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | 14842 | | | | |
| | | | 14769 | 14873 | | | |
| | | | 14665 | 15331 | | | |
| | | | 14647 | 15385 | | | |
| | | | 14586 | 15402 | | | |
| | | | 14395 | 15838 | | | |
| | | | 13809 | 15844 | | | |
| | | 12952 | 13789 | 15961 | 17015 | | |
| | | 12403 | 13713 | 16017 | 17203 | | |
| | | 12794 | 13682 | 16352 | 17239 | | |
| | | 12678 | 13637 | 16392 | 17361 | | |
| | | 12654 | 13312 | 16499 | 17635 | | |
| | 11571 | 12627 | 13276 | 16609 | 17661 | 18297 | |
| | 10598 | 12542 | 13132 | 16680 | 17670 | 18321 | |
| | 10528 | 12051 | 13037 | 16784 | 17697 | 19874 | |
| 10041 | 10339 | 11921 | 13023 | 16917 | 18033 | 20013 | 20520 |

The average production was 14,842 pounds ranging from a low of 10,041 to a high of 20,520. It can be seen that 10% of the daughters produced at a level less than 12,000 pounds of milk and another 10% produced at a level above 18,000 pounds of milk. These data illustrate the normal variation found in a trait such as milk production and indicate the need for consideration of the concept of variability in interpreting genetic information.

*Repeatability* is another concept which we must consider in evaluating differences in milk production from a genetic standpoint. Repeatability can be defined simply as the degree to which a certain trait will reoccur given a second chance. The concept is best illustrated by consideration of the example given in Table 4.

(Table 4 on next page)

Table 4
REPEATABILITY:
2X, 305-DAY, ME MILK RECORDS

| Year | Cow 1 | Cow 2 |
|---|---|---|
| 1965 | 13,491 | 12,950 |
| 1966 | 12,573 | 11,101 |
| 1967 | 13,211 | 14,922 |
| 1968 | 14,699 | 13,203 |
| 1969 | 15,834 | 15,175 |
| 1970 | 15,248 | 14,093 |

We see milk production records for two cows from each of 6 years. A quick glance at the data leads one to the conclusion that Cow 1 is superior to Cow 2. But, if we look only at the data for 1967, production from Cow 2 is superior to Cow 1. So we see that the superiority of Cow 1 over Cow 2 is not always repeated, therefore illustrating that the repeatability for milk production is less than 100%. Well designed scientific studies using mass data have determined that the repeatability for milk production is in fact about 50%. This means that the number of records we have for an individual cow affects how much we know about her production. Three records are better than two and two are better than one.

As previously indicated, only part of the difference in performance between cows is due to genetics. The rest is due to something else - *environment*. In order to characterize accurately the genetic contribution, environmental factors must be accounted for. One obvious environmental factor which affects production is the *length of lactation*. The 305-day lactation was adopted as the standard length for obvious reasons. Table 5 gives factors for projecting lactations shorter than 305 days.

Table 5
305-DAY PROJECTION FACTORS FOR MILK

| Days in Milk | Holstein | | Jersey | |
|---|---|---|---|---|
| | Under 36 mo. | Over 36 mo. | Under 36 mo. | Over 36 mo. |
| 30 | 8.32 | 7.42 | 7.65 | 7.14 |
| 45 | 5.54 | 4.96 | 5.14 | 4.79 |
| 60 | 4.16 | 3.74 | 3.89 | 3.63 |
| 75 | 3.35 | 3.02 | 3.17 | 2.95 |
| 90 | 2.82 | 2.56 | 2.68 | 2.50 |
| 120 | 2.16 | 1.98 | 2.09 | 1.96 |
| 150 | 1.77 | 1.64 | 1.73 | 1.63 |
| 180 | 1.51 | 1.41 | 1.48 | 1.41 |
| 210 | 1.32 | 1.26 | 1.31 | 1.26 |
| 240 | 1.19 | 1.14 | 1.19 | 1.15 |
| 270 | 1.08 | 1.06 | 1.08 | 1.07 |
| 300 | 1.01 | 1.01 | 1.01 | 1.01 |

DHI Letter ARS-44-169 (Vol. 41, No. 6) 1965

In order to compare production from different cows in the most accurate fashion, length of lactation must be considered; therefore, all records should be expressed on equal lactation-length basis.

Another environmental factor obviously needing consideration is *age* of cow. For sake of standardization we express age at the time of calving. The excepted method of considering differences in age for genetic evaluations is the use of mature equivalent production. Factors are available which allow for the adjustment of actual production to a standard age basis which we call mature equivalent (ME). Table 6 illustrates the degree of adjustment for 10 and 15-thousand pound production records at five different ages.

Table 6
COMPARISON OF ACTUAL AND AGE ADJUSTED RECORDS

| Age at Calving Months | Actual Production lbs | M.E. Production lbs |
|---|---|---|
| 24 | 10,000 | 12,800 |
| 24 | 15,000 | 19,200 |
| 36 | 10,000 | 11,700 |
| 36 | 15,000 | 17,550 |
| 48 | 10,000 | 10,700 |
| 48 | 15,000 | 16,050 |
| 60 | 10,000 | 10,200 |
| 60 | 15,000 | 15,300 |
| 72 | 10,000 | 10,000 |
| 72 | 15,000 | 15,000 |

USDA-DHI Letter, ARS 44-188, February, 1967

It can be seen that 72 months is the age of mature equivalent standardization.

Of particular interest in Florida is the effect of *season* and climate on level of production. Figure 1 illustrates graphically this phenomenon. It is easy to see that cows calving in the months of June, July, August and September are at a disadvantage. Again, for accurate evaluation of genetic differences the month of calving must be considered in order to eliminate this major environmental effect.

After consideration of these genetic principles and environmental factors which effect production, the following formula for rate of genetic progress can be written:

$$\text{Genetic progress per year} = \frac{\text{Accuracy X Selection Intensity}}{\text{Generation Interval}}.$$

In this equation, genetic progress is expressed in pounds of milk; accuracy is expressed as a percentage fraction; selection intensity is expressed as pounds of milk, and generation interval in years. An example to illustrate the use of this formula is given in the following example. If a dairymen selects the top five percent of AI sires, keeps any heifer out of the top 80% of his cows and his accuracy of sire selection is 90%, the accuracy of cow evaluation is 50% and his generation interval is 5 years, the following rate of genetic progress can be calculated.

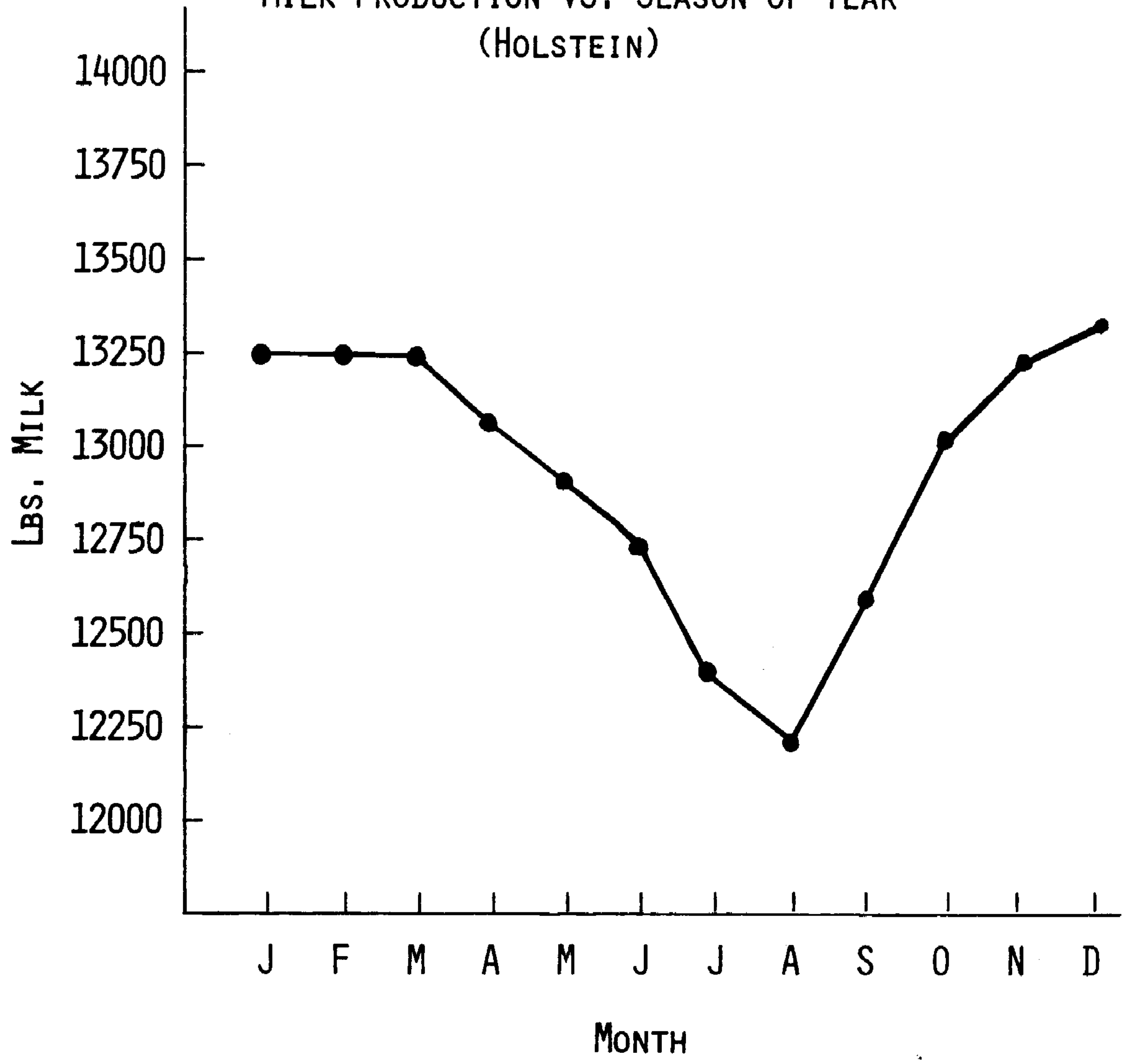
$$\text{Genetic Progress} = \frac{(.90 \text{ X } 1030) + (.50 \text{ X } 147)}{5}$$

$$= 200 \text{ lbs milk per year}$$

FIGURE 1

MILK PRODUCTION VS. SEASON OF YEAR

(HOLSTEIN)




USDA-DHI ME FACTORS

ARS-NE-40, SEPT. 1974.

It should be pointed out that this example is a highly selective genetic management program and may or may not be applicable to a particular operation. Nevertheless, it does illustrate the principle of expressing genetic progress on a unit/time basis.

The previous example indicated much more emphasis on sire selection pressure than on selection of dams. With high rates of cow-turnover, less than perfect reproductive efficiency and at least half the calves born are males, it is obvious that one cannot exert extreme selection pressure on females (dams). This leads us to consider the importance of the sire in the overall genetic management program. Figure 2 illustrates how the importance of sire selection increases over generations. With the advent of AI, maximum use can be made of genetically superior sires. Table 7 illustrates the growth of AI in the United States.

Table 7
GROWTH OF AI USAGE IN UNITED STATES

| Year | Number of Sires In AI Service | Number of Cows | Average Number of Cows per Sire |
|---|---|---|---|
| 1939 | 33 | 7,359 | 228 |
| 1940 | 138 | 33,977 | 246 |
| 1945 | 729 | 360,732 | 495 |
| 1950 | 2,104 | 2,619,555 | 1,245 |
| 1955 | 2,450 | 5,413,874 | 2,210 |
| 1960 | 2,544 | 7,144,679 | 2,808 |
| 1965 | 2,316 | 7,879,982 | 3,402 |
| 1970 | 2,275 | 8,578,778 | 3,644 |

From USDA-DHI Letter, ARS 44-233, July, 1971.
Data include dairy and beef cattle.

Notice that the big growth surge came in the 1950's with the advent of frozen semen. Certainly, with AI, many cows can be bred to one bull. This makes it all the more important that sires be chosen accurately and judiciously.

One important biological limitation of bulls is that they don't give milk; therefore, we must evaluate them on the basis of their daughters' production, i.e. progeny testing.

We are fortunate indeed to have the USDA-DHIA sire summary program. This program has been in existence for a number of years and has been modified extensively on several occasions. These modifications have improved the accuracy of the sire evaluations. There is no question that use of current USDA-DHIA sire summaries is mandatory for a meaningful program of genetic management at the farm. It is not the purpose of this paper to detail how the summaries are calculated. It is appropriate to illustrate the concept and to indicate what the information means. If we think of progeny testing for milk production, we must have a source of data. Data from the National Cooperative Dairy Herd Improvement Program (DHI) have served this need extremely well. With the advent of high-speed digital computers, adjustments for the environmental factors listed above can be

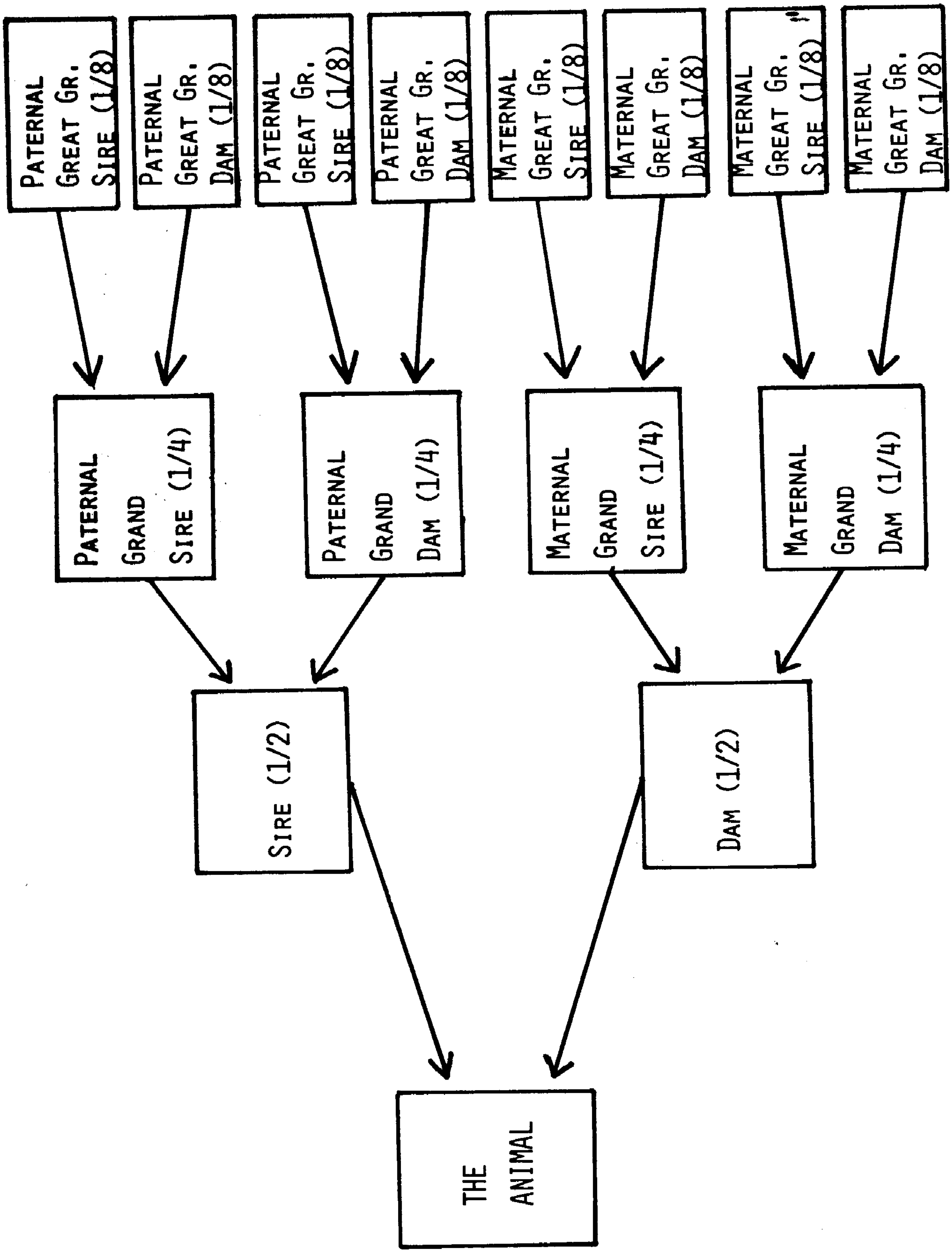

Paternal Great Gr. Sire (1/8)
Paternal Great Gr. Dam (1/8)
Paternal Great Gr. Sire (1/8)
Paternal Great Gr. Dam (1/8)
Maternal Great Gr. Sire (1/8)
Maternal Great Gr. Dam (1/8)
Maternal Great Gr. Sire (1/8)
Maternal Great Gr. Dam (1/8)
Paternal Grand Sire (1/4)
Paternal Grand Dam (1/4)
Maternal Grand Sire (1/4)
Maternal Grand Dam (1/4)
Sire (1/2)
Dam (1/2)
The Animal

Figure 2

made easily. In addition to the standard adjustments for age, length of lactation, season of calving, region of the country, frequency of milking and others, the computer makes many complicated mathematical manipulations quite easy. All of this results in more meaningful and more accurate information on which to base sire selection decisions.

A small portion of this concept can be illustrated by the ranking of eight AI bulls using different methods. In Table 8 we see a list of eight bulls ranked solely on the basis of their daughters' average production.

Table 8
BULLS RANKED BY DAUGHTER PRODUCTION

| | | Daughter Production | | |
|---|---|---|---|---|
| Bull | Rank | Milk | % | Fat |
| NAP | 1 | 22,887 | 4.01 | 917 |
| SKB | 2 | 20,806 | 3.44 | 715 |
| SDHJ | 3 | 20,199 | 3.49 | 705 |
| ACA | 4 | 19,816 | 3.44 | 682 |
| DVAJ | 5 | 19,484 | 3.48 | 678 |
| PFAC | 6 | 17,213 | 3.69 | 636 |
| PB | 7 | 17,126 | 3.54 | 607 |
| PC | 8 | 16,580 | 3.62 | 601 |

Keeping in mind that we want sire selection decisions based on accurate and sound information, we ask the question "Is there more?". How many daughters were there? How many herds were they in? Were they treated preferentially? Were they all in one herd, state or region? What was the production level of other cows in those herds? The USDA Sire Summary procedure allows us to answer these questions and account for them in our calculation of the sire summary.

In Table 9 we have ranked the same eight bulls not on daughter production but on daughter-herdmate differences.

Table 9
BULLS RANKED BY DAUGHTER-HERDMATE DIFFERENCE

| Bull | Original Rank | Daughter Production | Herdmate Production | DAU - HM Difference |
|---|---|---|---|---|
| NAP | 1 | 22,887 | 18,101 | 4,786 |
| DVAJ | 5 | 19,484 | 16,784 | 2,700 |
| ACA | 4 | 19,816 | 17,579 | 2.237 |
| SDHJ | 3 | 20,199 | 17,982 | 2,217 |
| PC | 8 | 16,580 | 14,400 | 2.180 |
| PB | 7 | 17,126 | 15,471 | 1,655 |
| PFAC | 6 | 17,213 | 15,591 | 1.622 |
| SKB | 2 | 20,806 | 19,646 | 1,160 |

We see that the number one bull is still number 1 but the number 5 bull has moved up to number 2 and the number 2 bull has moved to eight. If we go a step further and calculate the *predicted difference* (PD) which is the "cadillac" of sire evaluations, we see still a different ranking. The original number 6 bull is now first, number 7 is second and 1 has moved to third.

Table 10
BULLS RANKED BY USDA PREDICTED DIFFERENCE

| Bull | Orig Rank | Dau. Prod. | H.M. Prod. | No Daus | No Herds | PD Milk | PD Fat | PD $ | Repeat % |
|---|---|---|---|---|---|---|---|---|---|
| PFAC | 6 | 17213 | 15591 | 1201 | 698 | 1697 | 75 | 135 | 97 |
| PB | 7 | 17126 | 15471 | 197 | 100 | 1553 | 45 | 105 | 88 |
| NAP | 1 | 22887 | 18101 | 23 | 2 | 1238 | 64 | 105 | 24 |
| PC | 8 | 16580 | 14400 | 137 | 41 | 1167 | 41 | 85 | 57 |
| DVAJ | 5 | 19484 | 16784 | 17 | 4 | 870 | 26 | 60 | 30 |
| ACA | 4 | 19816 | 17579 | 30 | 2 | 667 | 21 | 47 | 26 |
| SDHJ | 3 | 20199 | 17982 | 18 | 1 | 577 | 15 | 38 | 22 |
| SKB | 2 | 20806 | 19646 | 18 | 4 | 543 | 7 | 30 | 32 |

Predicted difference (PD), expressed as milk, fat or dollars is the single figure that we use to indicate a bull's relative breeding value. You see also that the USDA data from which PD is calculated includes the level of herdmate production, the number of daughters, and the number of herds reflected in the proof. An index which indicates the quality of the data as determined by the number of daughters, number of herds and their distribution is the figure we refer to as *repeatability*, expressed as a percentage. The greater the repeatability, the more confidence we have in the data reflected in the proof.

One question asked frequently, "Well so what, does it work?". In short, the answer is, "Yes it does!". There is much data to substantiate this answer. A study done at the USDA Research Station in Beltsville, Maryland serves as a good example. They considered all the bulls used in their breeding program over the course of several years and grouped them into three groups. Group 1 sires had an average PD of -299, Sire group 2 averaged +284, and sire group 3 averaged +913. The results of over 250 daughters from these three bulls are summarized in Table 11.

Table 11
PERFORMANCE OF SIRES USED IN USDA HERD AT BELTSVILLE

| Sire Group | No. of Sires | Avg. PD | No. of Daus | Average Milk Production | Average Difference from Herdmates |
|---|---|---|---|---|---|
| | | lbs | | lbs | lbs |
| I | 5 | -299 | 101 | 15523 | -838 |
| II | 5 | +284 | 90 | 16259 | + 87 |
| III | 5 | +913 | 82 | 16913 | +622 |

USDA-DHI Letter, ARS 44-202, April, 1968.

These data clearly indicate that the daughters of the group 3 bulls were far superior to the daughters of either of the other two groups of bulls.

Another interesting study was revealed from Pennsylvania State University in March of this year. Researchers there looked at sons of bulls as an evaluation of their sires' genetic contribution. Any bull with 20 or more proven sons was considered. The bulls were ranked according to the average predicted difference for milk of their sons. Fifteen of those bulls were selected for this example and are given below in Table 12.

Table 12
SIRES WITH 20 OR MORE SONS IN AI

| Bull | Bulls PD Milk | No. of Sons | Average PD Milk for Sons | Number of Sons +PD Milk | Number of Sons -PD Milk |
|---|---|---|---|---|---|
| Pawnee Farm Arlinda Chief | +1449 | 150 | +435 | 139 | 11 |
| Paclamar Bootmaker | +1110 | 110 | +427 | 98 | 12 |
| Whirlhill Kingpin | +1178 | 180 | +402 | 160 | 20 |
| Zimmerman Alstar Pilot | + 768 | 94 | +326 | 79 | 15 |
| Paclamar Astronaut | + 844 | 129 | +275 | 99 | 30 |
| No-Na-Me Fond Matt | + 602 | 89 | +197 | 68 | 21 |
| Harborcrest Sunshine | + 650 | 101 | +171 | 73 | 28 |
| Irvington Pride Admiral | + 427 | 266 | + 43 | 133 | 133 |
| Gray View Skyliner | + 385 | 232 | + 3 | 115 | 117 |
| Osborndale Ivanhoe | + 392 | 347 | - 19 | 162 | 185 |
| Romandale Reflection Marquis | - 631 | 519 | -109 | 38 | 481 |
| Ideal Fury Reflector | - 412 | 239 | -288 | 44 | 195 |
| Glenafton R.A. Hagen | - 574 | 66 | -499 | 2 | 64 |
| Paclamar Ivanhoe Black Eagle | - 677 | 145 | -485 | 14 | 131 |
| Thonyma Ormsby Senator | -1089 | 106 | -571 | 9 | 97 |

From L.W. Specht, Pennsylvania State University, 3/76.

We see that the number 1 bull is Pawnee Farm Arlinda Chief whose PD for milk himself was +1449. He had 150 sons with AI proofs. Their average PD was +435; 139 were plus and only 11 were minus in PD for milk. One bull, Romandale Reflection Marquis whose PD was -631, had 519 sons in the summary. Obviously this bull was used heavily for reasons other than milk production. The average PD of his sons was -109. Of the 519 sons with AI proofs, 481 were minus for milk and only 38 were plus.

Dairymen have a basic tool to evaluate cows producing ability, i.e. DHI records. Environmental factors affect production and must be taken into account if we are to asses accurately the genetic ability of a cow or a group os cows. Three factors which have an obvious effect on production are length of lactation, time milked per day and age. To standardize these we express production records on a 305-day, 2X, ME basis. Breed, herd, year and season are accounted for by comparing a cow's records to those of her herdmates in expressing them as deviations. Certain temporary factors frequently affect the cows production during the lactation. Some of these are days dry, days open, sickness or injury. These can be accounted for by averaging all of their records available. The only feasible means for today's dairy farmer to utilize knowledge of these concepts in his genetic management program, is for him to be enrolled in the DHI program. This modern, flexible, computerized program offers all of the above considerations and adjustments on a routine inexpensive basis. Certainly it is an inexpendible tool for genetic management.

In summary, we should consider the following points in developing a program for genetic management.

1) A good program of general herd management will allow for more intensive culling.

2) Home-raised replacements provide the greatest opportunity for genetic improvement through intelligent selection of proven AI sires.

3) If young bulls are used in a herd, select good ones based on sound information and don't use one bull too long.

4) No beef bulls should be used on dairy cattle.

5) Dairymen who purchase replacements should base their purchasing decisions on as much sound information as possible about the quality of cattle under consideration.

6) Basic genetic principles should be considered in the development of a program for genetic management.

7) Genetic management decisions should be based on facts using DHI production records as tools.

8) Genetic progress will be obtained if a long-range plan for genetic management is adopted and followed. No plan will lead to no progress.