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Editors
W. Christopher Scruton
Stephen Claas

Layout
David Brown

Logo Design
Ruth Cronje, and Jan Swanson;
based on the original design by Dr. Robert Dunlop

Cover Design
Sarah Summerbell

Role of genetics in gilt attrition

Rodger Johnson, PhD

University of Nebraska, Animal Science Department

Lincoln, Nebraska

Whether developing gilts from a within-herd multiplication system or purchasing them from a genetic supplier, pork producers have a significant investment in replacement gilts. Average genetic premiums for replacement gilts currently are approximately $80 per gilt. The return to commercial producers from this investment depends on the length of productive herd-life of the gilt.

It is well known that environmental factors such as health, nutrition, and management of gilts during development; and nutrition and management of sows during gestation and lactation affect sow attrition rates. Less is known about genetic effects on gilt attrition rates and sow longevity. Much research on genetics of reproductive traits such as age at puberty, ovulation rate, embryo survival, uterine capacity, and litter size has been conducted. These traits are heritable, differ among breeds, and are affected by crossbreeding. However, little work to determine how these traits contribute to sow longevity has been done. Until recently, we could not be sure whether selection for increased sow longevity and lower gilt attrition rates would be effective.

Results of the recent NPPC Maternal Line Evaluation Project (MLP) clearly show that genetics have a very important role in gilt attrition rates and in sow longevity. In that project, gilts from six commercial lines were sampled and productivity through four parities was evaluated.

Approximately 550 165-day gilts of each genetic line were studied. Five of the lines had very similar gilt and sow attrition rates and sow longevity. The percentage of gilts that completed four parities ranged from 48.1% to 52.4% for these five lines and on average age of sows at culling ranged from 476 to 484 days. Sows of these lines accomplished this result in almost exactly the same way. They had similar ages at puberty, ages at farrowing each litter, and attrition rates at all ages. These lines differed in litter size, growth rate, and in percentage carcass lean. One might conclude from these results that there is little genetic variation involved in gilt and sow attrition rates and that these rates are not related to the production characteristics of the line. However, one line—the Monsanto DeKalb MXP200 entry—was far superior to all other lines. Seventy percent of the MXP200 gilts produced four litters and they had an average life of 546 days.

The MXP200 gilts were a unique entry to the MLP, being a cross between the DeKalb Genepacker(r) female and boars of a line developed at the University of Nebraska. The objective of this paper is to discuss results of the MLP, to describe the selection history of the Nebraska line, and to discuss the genetic contribution of this line to the special reproductive performance of MXP200 females.

The NPPC MLP Project

The MLP was conducted in response to pork producers' needs for comprehensive evaluation of sow productivity. It is the most complete evaluation of maternal lines ever conducted in the US. Project objectives were to measure lifetime productivity through four parities of sows of different maternal lines, and to evaluate the performance of market pigs produced by these sows. A total of 3,559 early-weaned gilts entered the program. All were F1 crosses representing products of five breeding organizations (**Table 1**)

The lines designated as Danbred USA, DEKALB Monsanto DK44, American Diamond Genetics, and Newsham Hybrid are commercial products marketed by the respective organizations. Each is an F_1 cross among the company's maternal lines, closed breeding lines that were developed and selected for maternal traits. In most cases these lines originated from the Landrace and Large White/Yorkshire breeds, but might also include introductions from other breeds in the line development.

The National Swine Registry entry is an F_1 Yorkshire-Landrace cross gilt produced in cooperator purebred herds. The gilt was produced by crossing Yorkshire boars with Landrace females and by the reciprocal cross.

The sixth line, the DEKALB Monsanto MXP200 entry, is a cross between the DEKALB Monsanto Genepacker(r) with an experimental line developed at the University of Nebraska. The Nebraska Index Line is a composite population of Large White and Landrace that was closed in 1981 and then selected 16 generations for increased ovulation rate, embryonic survival and litter size at birth. The MXP200 gilts were produced by crossing Index line boars with DEKALB Monsanto Genepacker(r) sows. DEKALB Monsanto purchased samples of the Index line from the

Table 1. Number of gilts entered per line per entry group

Line	*Feb. 12, 1997*	*March 5, 1997*	*April 16, 1997*	*Total*
American Diamond Genetics (ADG)	230	180	180	590
Danbred USA (DB USA)	179	139	268	586
DEKALB Monsanto DK44 (DK44)	132	189	272	593
DEKALB Monsanto MXP200	172	241	179	592
National Swine Registry[a] (NSR)	261	133	173	567
Newsham Hybrids USA (NH)	235	178	218	631
				3,559

[a] National Swine Registry entered Yorkshire * Landrace F_1 cross gilts

University of Nebraska and maintains this line at their nucleus farm.

Gilts entered the MLP in three groups beginning in February 1997, with approximately an equal number from each line in each group. The numbers of gilts per line per entry group are shown in Table 1. The project continued until the last litters were weaned in August 1999.

Culling Procedures

Details of the MLP were reported in the NPPC Maternal Line National Genetic Evaluation Program Results. Normal production practices for gilt development and sow management were used. The early-weaned gilts that entered the program were culled only for death, hernias, or for poor health. Approximately 92% of the gilts entered the breeding units. The time-clock for sow longevity began when gilts were moved to breeding units at 165 days of age. From then on, females were culled only because of reproductive failure or because of death.

Gilts were culled if they failed to express estrus by 300 days of age or if they failed to conceive during a 60-day breeding period. Gilts were given a maximum of three opportunities to breed.

Litters were weaned at 15 days of age and sows were observed for expression of estrus each day thereafter. They were mated on the day they first expressed estrus and again every 24 hours while still in estrus. Sows were culled if they failed to conceive within 50 days of weaning their litter. No culling on the basis of litter size was practiced.

Results

Table 2 contains the number of gilts of each line that entered the breeding units, their age at first observed estrus, and the percentage that farrowed litters. Five lines had almost identical performance, but the MXP200 gilts were uniquely different. Approximately 10% more expressed estrus and they were 12 to 15 days younger at first estrus. Thus, in most genetic lines, breeders can expect approximately 10% attrition because replacement gilts do not express estrus. Also, in most lines, approximately 75% of the replacement gilts are expected to farrow a litter. However, 92% of the MXP200 gilts had a P1 litter. Thus, MXP gilts had a lower attrition rate to production of P1 litters than all other lines. This lower rate occurred because more of them expressed estrus and conception rates were also higher as more of those that did express estrus also far-

Table 2. Gilt age at first estrus and first farrowing

Line	*Number gilts*	*% showing estrus*	*Age at first estrus (days)*	*% gilts farrowing*	*Age at farrowing (days)*
ADG	562	91	225^b	77	371^b
DB USA	541	87	222^b	77	366^b
DK44	550	87	222^b	75	367^b
MXP200	547	97	209^a	92	354^a
NSR	515	90	222^b	77	367^b
NH	568	88	223^b	78	368^b
	3,283				

Least squares means with the same superscripts are not different ($P<.05$)

rowed a litter. The advantage of MXP200 gilts in age at first estrus carried over to the same difference in age a first farrowing.

Tables 3 and **4** contain results of a cohort analysis of the MLP data. A cohort was defined as 25 165-day-old replacement gilts. The results are the expected output per gilt for each group of 25 replacement gilts introduced into the herd.

The MXP200 females had greater fertility and lower attrition rates throughout their life. Through four litters they produced approximately 80 litters, an average of 3.2 litters per replacement gilt, compared to approximately 60 litters per cohort (average of 2.4 litters per gilt) for other lines. This advantage of approximately 33% more litters per replacement gilt was due to 15.2% lower attrition rate from 165 days to first parity (Table 1) that accounted for 3.8 litters per cohort, and to uniformly lower attrition rates after each subsequent parity that accounted for the remaining difference of 16 litters per cohort. Seventy percent of MXP200 gilts produced four litters compared with 51% for other lines (Table 4). Their average length of life was 14% longer than for other lines (546 days compared with 479 days).

In addition to being more fertile and having lower attrition rates, MXP200 females also gave birth to more live pigs and weaned more pigs per litter than other lines (Tables 3 and 4). The combination of larger litters and lower attrition rates resulted in 43% more live pigs per replacement female for MXP200 females than for the average of other lines. This advantage ranged from 33% advantage over DK44 females to 51% advantage over American Diamond Genetics females.

MXXP200 females were smaller at farrowing and lost more weight during lactation than other lines (**Table 5**). They were intermediate in backfat to other lines, but lost the most backfat during lactation. As a percentage of farrowing weight and backfat thickness, MXP females lost 11.9% of their weight during lactation compared with 9.3% for other lines and they lost 9.5% of their backfat compared with 6.4% for other lines (Table 5). The greater loss of weight and backfat during lactation was due partly to lower feed intake (Table 4). TMXP200 females consumed approximately 1 lb less food per day than other lines. Lower feed intake during lactation was due to lower body weight as food intake as a percentage of farrowing weight was approximately 2.35% for all lines.

Generally, sows with lower feed intake and greater weight and backfat losses during lactation have longer wean-to-service intervals, and greater post-weaning sow attrition rates. However, the MXP200 is an exception. Their wean to service intervals were consistently less than for all other lines, and a higher percentage of sows consistently mated

Table 3. Results of cohort analysis (a cohort is 25 165-day-old replacement gilts)

Line	*Litters/ cohort*	*Litters/ sow/yr*	*Live pigs/litter*	*Live pigs/cohort*	*Live pigs/ sow life*	*Live pigs/ sow/yr*
ADG	60.7b	1.84b	9.37d	570c	22.8c	17.3d
DB USA	61.4b	1.87b	9.87c	608bc	24.3b	18.5c
DK44	62.7b	1.89b	10.35b	650b	26.0b	19.6b
MXP200	79.6a	2.12a	10.82a	864a	34.5a	23.1a
NSR	60.1b	1.86b	9.69c	586c	23.4c	18.2c
NH	62.8b	1.88b	9.59cd	604bc	24.2bc	18.1cd

Means with common letter are not different, *P*<.05

Table 4. Results of cohort analysis (a cohort is 25 165-day-old replacement gilts)

Line	*Pigs weaned/ cohort*	*Pigs weaned/l itter*	*Pigs weaned/s ow/yr*	*Avg d sow life*	*Sows (%) producin g 4 litters*	*Sow lact feed intake*
ADG	526c	8.66f	15.9d	481b	50.3b	12.1a
DB USA	547bc	8.92c	16.7bc	476b	48.1b	11.5b
DK44	573b	9.15b	17.3b	482b	50.3b	11.6b
MXP20 0	747a	9.39a	19.9a	546a	69.9a	10.7c
NSR	532bc	8.86d	16.5c	470b	52.4b	11.6b
NH	551bc	8.77c	16.5c	484b	52.1b	11.6b

Means with common letter are not different, *P*<.05

during the first 10 days after weaning their litters (Table 5). Their advantage was greatest after the P1 litter, but they also had better rebreeding performance after their third litter.

Other characteristics of MXP females

Data for other traits of the lines are not presented here, but can be found in the NPPC MLP Program Results. All characteristics of MXP200 females compared with other lines in the MLP were not positive. For example, they had lower 15-day litter weaning weight indicating they had lower milk production than other lines. In addition, their progeny grew more slowly, had less lean at market weight, and poorer feed conversion ratios than other lines. Therefore, the increased reproductive advantage of MXP200 females must decrease costs of production enough to offset the lower value of progeny to make the line commercially acceptable.

Genetic basis for the reproductive advantage of MXP females

Results of the MLP clearly show that there is a genetic component to sow longevity and sow attrition rates. If lines differ significantly when compared in the same environments and proper sampling procedures are used, differences between them can be due to additive genetic differences among lines and to differences in proportions of heterosis they express. Additive differences are due to direct effects of genes and thus are heritable differences.

The MXP200 is a cross of a line developed at Nebraska and the Monsanto DeKalb Genepacker(r). The Genepacker(r) is a cross of Monsanto DeKalb grandparent lines. One of these lines was also a grandparent of the DK44 female. Both of these lines—as well as all other lines in the MLP—expressed 100% maternal heterosis, and all females were mated to Danbred terminal sires and produced litters with 100% heterosis in the pigs. Thus, females of all lines and their progeny expressed 100% heterosis, so differences in heterosis did not contribute to differences found in the MLP.

Additive line differences are due to accumulated effects of selection in the development of lines. The selection history of the Monsanto DeKalb lines that make up the Genepacker(r) is not known. However, the selection background of the Nebraska line is well documented, and it is believed that a significant proportion of the advantage of the MXP200 females was due to the genetic superiority for reproduction as a result of this selection.

The Nebraska Index Line

The Nebraska Index Line is a composite of Large White and Landrace (with 50% of its genes coming from each breed) that has been selected for increased ovulation rate, embryonic survival, and litter size. The initial cross of the breeds occurred in 1979 and the line has been managed as a closed breeding population since then with no outside introductions. Beginning in 1981, selection for increased index of ovulation rate and embryonic survival began. The selection policy was very strict. In each generation, all gilts from every litter (150–200 gilts from 45 litters) were mated, laparotomies were performed at 50 days of gestation to count corpora lutea and number of fetuses, and the 25–30% of the highest indexing gilts were farrowed. All other gilts were culled, regardless of their ovulation rate, number of fetuses, or other performance

Table 5. Sow weights, backfats, and rebreeding performance

Line	*Sow farrow wt, lb*	*Sow lact. Wt loss, lb*	*Sow BF at farrow, in*	*Lact BF loss, in*	Percentage of sows serviced 0 to10 days and wean to service interval (in parenthesis) *P1*	*P2*	*P3*
ADG	511b	48.3b	.91e	.056bc	67.1 (14.9b)	86.2 (10.0)	77.7 (11.4b)
DB USA	495c	48.0b	.66a	.040a	66.5 (14.9b)	82.0 (9.5)	77.2 (10.1ab)
DK44	523a	47.1b	.82d	.05ab	71.3 (12.8a)	83.3 (9.6)	79.6 (9.1a)
MXP200	455d	54.3c	.78c	.074d	77.9 (11.2a)	88.5 (8.2)	86.6 (8.5a)
NSR	497c	47.0b	.81d	.062c	63.8 (15.9b)	85.7 (9.5)	82.6 (9.5a)
NH	491c	43.2a	.70b	.041a	66.0 (15.0b)	85.2 (9.7)	78.4 (9.6a)

Means with common letter are not different, *P*<.05.

characteristics. Boars were retained from the 15 high indexing females and were mated to the gilts of these litters for the next selection cycle. Generation interval was one year. A randomly selected control to monitor genetic change was maintained. For a complete description of this line see Johnson et al., 1999.

Index selection continued for 10 generations and resulted in an increase of 6.7 ova and approximately 3.2 pigs at birth. After index selection was terminated, the line was maintained with 45 litters per generation until generation 14 when it was increased to 90 litters. Selection during this period was for increased litter size at birth with females selected from the largest 30% of the litters and boars from the largest 15 litters. Generation interval continued to be one year. Currently, the inbreeding coefficient of the line is approximately 20%.

Compared to the control line, the Index line currently has approximately 4 more pigs per litter, averaging 13.5–14.0 fully formed pigs during the last three generations. Gilts of the line reach puberty approximately 10 days earlier than Control line gilts. The line also has very high conception rates, nearly always above 90% and in some generations being as high as 95–98%. The index and control lines do not differ in rate of growth or backfat thickness.

During its development, no intentional selection for decreased age at puberty, for increased conception rate, or for sow rebreeding performance was practiced. Because only gilts were farrowed, it was not possible to select for sow rebreeding performance. Breeding was at the same time each year and gilts were given a maximum of two opportunities to get pregnant. Thus, there was little opportunity for gilts with old ages at puberty or low fertility to be selected. Those that did not conceive during the breeding period were culled and did not leave offspring. Therefore, the low attrition rate and increased longevity of the MXP200 females were likely due to the increased additive genetic effects of the Nebraska Index Line directly attributable to the strict selection policies applied in its development over a 16-generation period.

It is well known that age at puberty and wean to service intervals are heritable. Both traits have responded to selection in controlled selection experiments (e.g., Lamberson et al., 1991; ten Napel et al., 1997, 1998). Heritability of age at puberty is approximately 25–30% and heritability of wean-to-service interval is 15–20%. Also, heritability of litter size is about 10% in most populations, but was approximately 16% in the Nebraska Index line. Therefore, some of the traits involved in the superior lifetime productivity and lower attrition rates of the MXP200 females are heritable and will respond to selection.

Direct selection for decreased wean-to-service interval, longevity, or decreased attrition rates was not practiced in the Nebraska Index line, nor have these traits been compared between the index and control lines. Any advantage the line has in these traits either existed in the base population or were correlated responses to the selection that was applied.

Summary

The MLP project clearly demonstrated that traits that contribute to sow attrition rates and to sow longevity are heritable. The advantage of the MXP200 line was likely due to effects of long-term selection for increased ovulation rate, embryonic survival, and litter size practiced over a 16-generation period. These traits have low to moderate heritability, and because they are measured only in females and late in life are difficult to select for. Furthermore, selection only for these traits, even in maternal lines, is not recommended. Growth and carcass traits must also be considered in maternal line development. Selection for traits related to low sow attrition rates is expected to result in improvements, but the rate of change will be slow. It will be very difficult to detect changes over a time-period of even 5–7 years. It is only when strict selection over a long time-period is practiced that detectable genetic changes will occur.

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