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Reproduction of 3/4 White Composite and 1/4 Duroc, 1/4 Meishan, 1/4 Fengjing, or 1/4 Minzhu gilts and sows

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Reproduction of $\frac{3}{4}$ White Composite and $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu Gilts and Sows^{1,2}

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ABSTRACT: Females were either $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu, and the remainder were $\frac{3}{4}$ White Composite. A greater percentage of Fengjing crosses reached puberty than Duroc or Minzhu ($P < .05$), and Meishan crosses were intermediate and not different ($P > .05$) from other breed types. After adjusting for differences in percentage detected owing to termination of observation for estrus, breed types ranked Fengjing, Meishan, Minzhu, and Duroc from youngest to oldest at puberty with approximately 14 d between adjacent breed types. Meishan and Fengjing crosses had a greater ($P < .05$) ovulation rate than Minzhu or Duroc crosses. With the exception of number of fetuses at 100 d and average fetal weight at 60 d, differences among breed types were not detected ($P > .05$) for litter or uterine traits measured on gilts slaughtered at 60 or 100 d of gestation. Total number of pigs born was greater ($P <$

$.05$) for $\frac{1}{4}$ Fengjing than for $\frac{1}{4}$ Duroc gilts. Gestation length, number born alive, number weaned, litter birth weight, or litter weaning weight for gilts did not differ ($P > .05$) among breed types. Duroc crosses were heavier ($P < .01$) than Chinese crosses at d 1 and 28 after farrowing, but breed types did not differ ($P > .05$) for backfat thickness at those times. Breed types did not differ ($P > .05$) for the ratio of litter gain from 0 to 28 d/total Mcal or any of the component traits in the ratio. Postweaning estrus activity, conception rate, and litter and uterine traits of sows bred for second parity were not affected ($P > .05$) by breed type. These analyses indicate that crossbred gilts containing $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu will reach puberty earlier, have larger litters, and weigh less at first parity than gilts containing $\frac{1}{4}$ Duroc, but they do not have any significant advantage in litter size at second parity.

Key Words: Breeds, Litter Size, Puberty, Ovulation Rate

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Introduction

Sow productivity is one of the most important performance traits affecting the efficiency of a swine enterprise (Tess et al., 1983). Crossbreeding programs are used to improve reproduction by exploiting breed additive effects, breed maternal effects, and heterosis. Meishan, Fengjing, and Minzhu are among the most highly prolific breeds in the People's Republic of China (Li and Enfield, 1989). Meishan have higher reproduction than French and English Large White (Legault and Caritez, 1983; Haley and Lee, 1990). Similar results were found in the United States

(Christenson, 1993; Christenson et al., 1993; White et al., 1993; Young, 1993, 1995a).

Data on carcass traits (Young, 1992a), growth (Young, 1992b), and reproduction (Young, 1995a) of first-cross Duroc, Meishan, Fengjing, and Minzhu have been reported. Young (1995b) presented growth and carcass data on pigs that were $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu. The adverse effects of $\frac{1}{4}$ Chinese germplasm on growth and carcass leanness likely preclude the use of $\frac{1}{2}$ Chinese dams in commercial swine production. Consequently, the reproductive performance of $\frac{1}{4}$ Chinese females and the developmental growth of their progeny are of interest. The objective of the research reported here was to evaluate reproductive traits of females that are $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu.

Experimental Procedures

Females were either $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu, and the remainder were $\frac{3}{4}$ White Composite. All females were born during two

¹Sadly, Dr. Young passed away after this paper had been submitted to *JAS*. Sincere appreciation is extended to Greg Leymaster for completing the revision of this paper.

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farrowing seasons (beginning mid-January and mid-July of 1991) and were the progeny of 47 White Composite boars mated to first-cross gilts. Most White Composite boars were mated to females of each F₁ breed type. First-cross gilts were produced by mating eight Duroc, nine Meishan, eight Fengjing, and seven Minzhu boars to White Composite females. Each original sire was represented by granddaughters in this experiment. White Composite boars and females were from advanced generations of an *inter se*-mated, composite population with equal contribution from Chester White, Landrace, Large White, and Yorkshire.

In each season, 60 gilts from each breed group were placed in finishing pens at 63 d of age with 20 gilts per pen. Breed groups were penned separately. Management and performance of gilts from birth to 154 d of age were reported by Young (1995b). Daily checks for estrus were initiated when gilts were moved to the finishing pen and continued to the end of their first breeding season. Gilts were recorded as being in estrus if they stood in response to back pressure or mounting by the boar. Puberty was defined as the first observed estrus followed by a second estrus approximately 21 or 42 d later, or when the gilt mated during the breeding season. Gilts were moved to a breeding building when gilts in a pen averaged approximately 100 kg. Each breeding season was 42 d in duration, and gilts were bred to produce their first litter at approximately 1 yr of age. During the breeding season, gilts were checked for estrus in the morning. Gilts were mated in the afternoon and thereafter at 12-h intervals to the same boar until the end of estrus. All gilts detected in estrus during the breeding season were mated. The number of pregnant gilts exceeded the capacity of the farrowing facility. Equal numbers of gilts from each breed group were chosen to farrow each season. Gilts were chosen at random from gilts bred during approximately the first 21 d of each breeding season to represent as many parents as possible. This restriction reduced age variation for progeny evaluated for growth.

Gilts in excess of the farrowing capacity were slaughtered at 60 or 100 d of gestation. The entire reproductive tract was collected at slaughter. The tract consisted of the broad ligament, ovaries, and all uterine tissues from the ovaries to the posterior end of the cervix. Gravid uterine weight, number of corpora lutea (ovulation rate), sex and weight of each fetus, and empty uterine weight were recorded. Placenta and other fetal membranes were included in empty uterine weight. Thus, the difference between gravid uterine weight and empty uterine weight was due to removal of the ovaries, fetuses, and allantoic and amniotic fluids associated with each fetus.

Gilts were moved into farrowing crates at 110 d of gestation. On the 1st and 28th d after farrowing, gilts were weighed and backfat was measured ultrasonically (Renco Lean Meter, Minneapolis, MN) 2.5 cm off the midline at the first rib, last rib, and last lumbar

vertebra. Feed consumption during lactation was recorded daily for each gilt from 1 d after farrowing (d 1) to weaning (d 28). Gilts were gradually returned to ad libitum consumption within 5 d after farrowing.

Pigs were weighed within 12 h after birth and at 14 and 28 d of age. After 14-d weights were recorded, each litter was allowed ad libitum access to creep feed. The amount of creep feed added was recorded each day. The amount of creep feed left by each litter was weighed when pigs were weighed at 28 d. Feed disappearance was used to approximate creep feed consumption by the litter.

Litter weight at weaning was considered to be the main output of interest from a pregnant sow. Because feed inputs of the sow and pig were measured only during lactation, output was measured as total gain from birth to weaning for all pigs weaned. Feed inputs were consumption of feed during lactation by the sow, consumption of creep feed by the pigs, and feed consumption during gestation that was required to gain the weight lost by the sow during lactation. Because diets differed in composition, all feed inputs were converted to megacalories of ME from feed and summed to provide a single estimate of total feed energy inputs. Details of the procedure were described by Young (1995a). Records were deleted if feed or weight records were incomplete (two Meishan, four Fengjing, eight Minzhu, and four Duroc-cross litters) or if sows received cross-fostered pigs (one Meishan, two Fengjing, and one Duroc-cross litter).

After weaning their first litter, females were returned to the breeding building and monitored daily for estrus. Females were bred at first and second detected estrus if the first estrus occurred within 30 d after weaning. Sows were slaughtered at 100 d of gestation to measure ovulation rate, gravid and empty uterine weight, fetal number, and fetal weight. Procedures were the same as those described for gilts.

Data were analyzed by least squares, mixed-model procedures (Harvey, 1985). The basic model included effects of breeding season (April or October), sire of gilt within breeding season, breed type ($\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu), breed type \times breeding season, and sire within breeding season \times breed type. Sire of gilt within breeding season and sire within breeding season \times breed type were assumed to be random, and all other effects were assumed to be fixed. Effect of breeding season was tested against sire of gilt within breeding season. Breed type and breeding season \times breed type were tested against sire within breeding season \times breed type. If the F-test for breed type was significant ($P < .05$), the six pairwise linear contrasts were made among breed type means. For a detailed discussion of Type I error rates under these conditions, see Young (1995a).

Preliminary analyses were conducted to determine sex effects on fetal weight at 60 and 100 d of gestation and pig weight at birth and weaning. Adjustment factors from these analyses were used to adjust

Table 1. Least squares means, standard errors, and levels of significance for breed type, season, and breed type \times season effects on percentage pubertal, puberty age, and interval from puberty to breeding for backcross gilts

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
Percentage pubertal ^a					
No. of observations	132	142	144	135	—
Mean	74.7 \pm 4.8 ^c	84.8 \pm 4.4 ^{cd}	92.6 \pm 4.7 ^d	74.9 \pm 4.6 ^c	.02
Age at puberty, d					
No. of observations	96	123	133	102	—
Observed mean	231 \pm 6 ^c	213 \pm 5 ^d	200 \pm 6 ^e	216 \pm 6 ^d	<.01
Adjusted mean ^b	248	221	206	235	—
Days from puberty to breeding					
No. of observations	64	85	89	69	—
Mean	30.8 \pm 4.9 ^c	42.8 \pm 4.4 ^{de}	53.3 \pm 4.6 ^e	38.2 \pm 4.8 ^{cd}	<.01

^aPercentage of gilts that exhibited a pubertal estrus by the end of their first breeding season when bred to farrow at one year of age.

^bAssuming the observed mean is from a truncated normal distribution.

^{c,d,e}Means within a row lacking a common superscript letter differ ($P < .05$).

individual fetal or pig weights to the average weight of males and females. Sex-adjusted individual fetal or pig weights were summed to give litter weights representative of litters with equal numbers of males and females.

Estrus detection terminated at the end of the breeding season; thus, age at puberty was not determined for all gilts. Observed means for age at puberty would be appropriate if all gilts were detected in estrus or if gilts not detected in estrus were cyclic but not exhibiting a behavioral estrus. Gilts not detected in estrus by the end of the breeding season were slaughtered and approximately 90% were prepubertal. Thus, the observed means are biased downward in varying degrees, depending on the percentage of gilts exhibiting puberty. Procedures outlined by Dickerson and Laster (1975) were used to adjust the observed least squares means of age at puberty for differences among breeds in percentage detected in estrus. Within subclass, standard deviations were used. Means for age at puberty were adjusted by subtracting $i\sigma_x$, where i is the expected (negative) deviation in σ_x units from true mean for the "selected" sample of observed ages at puberty and σ_x is estimated for a nontruncated distribution from the observed σ'_x as σ_x/σ_s where $\sigma_s^2 = 1 - i^2 + iZ$, and Z is deviation in σ'_x units from true mean at the point of truncation of a normal distribution.

Results and Discussion

Puberty Traits. A greater ($P < .05$) percentage of Fengjing crosses reached puberty than Duroc or Minzhu, and Meishan crosses were intermediate and not different ($P > .05$) from other breed types (Table 1). For gilts detected in estrus, Fengjing crosses were

significantly younger than Meishan or Minzhu crosses, which were younger than Duroc crosses. After adjusting for differences in percentage detected owing to termination of observation for estrus, breed types ranked Fengjing, Meishan, Minzhu, and Duroc from youngest to oldest at puberty with approximately 14 d between adjacent breed types. For days from puberty to conception, breed types ranked Fengjing, Meishan, Minzhu, and Duroc from highest to lowest; all differences were significant except between adjacent means. Assuming a 21-d estrous cycle, average cycle of conception was 3.5, 3.0, 2.8, and 2.5 for Fengjing, Meishan, Minzhu, and Duroc crosses, respectively.

Mean age at puberty of gilts that farrowed differed from that of slaughtered gilts by -7 , $+3.0$, -6.4 , and -6 d for Meishan, Fengjing, Minzhu, and Duroc crosses, respectively. Mean days from puberty to conception of gilts that farrowed differed from that of slaughtered gilts by -8.4 , -10.6 , -8.6 , and -19.8 d for Meishan, Fengjing, Minzhu, and Duroc crosses, respectively. Approximately one-third of Meishan and Fengjing and at least two-thirds of Duroc-cross gilts slaughtered were not detected in estrus during the first 21 d of the season or conceived at their second mating. For Minzhu crosses, most of the difference between the two samples for days from puberty to conception was due to the slightly later puberty of the slaughtered gilts. Young (1995a) reported that 100% of first-cross Meishan and 99% of first-cross Fengjing gilts reached puberty by the end of their first breeding season compared to 89 and 56% of first-cross Minzhu and Duroc, respectively. Age at puberty adjusted for percentage detected in estrus was 146, 149, 203, and 265 d for first-cross Meishan, Fengjing, Minzhu, and Duroc, respectively.

Traits Measured at Slaughter on Pregnant Gilts. Least squares means for ovulation rate are presented

Table 2. Least squares means and standard errors by breed type of gilt for reproductive traits measured at 60 and 100 d of gestation on first-parity, backcross gilts

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations					
60-d	12	21	21	13	—
100-d	12	22	24	12	—
Ovulation rate					
60-d	12.3 ± .7	13.0 ± .5	13.2 ± .5	11.9 ± .6	.33
100-d	10.8 ± .7 ^a	13.4 ± .5 ^b	13.1 ± .4 ^b	12.0 ± .6 ^b	.02
Overall	11.6 ± .5 ^a	13.2 ± .3 ^b	13.1 ± .3 ^b	12.0 ± .4 ^a	.01
No. of fetuses					
60-d	10.9 ± .7	10.0 ± .5	11.1 ± .4	10.0 ± .6	.28
100-d	7.7 ± .8 ^a	11.2 ± .5 ^b	10.8 ± .5 ^b	9.7 ± .7 ^b	.01
Fetal survival, %					
Unadjusted					
60-d	89 ± 5	79 ± 3	85 ± 3	86 ± 4	.24
100-d	73 ± 5	84 ± 3	82 ± 3	80 ± 5	.35
Adjusted for ovulation rate					
60-d	88 ± 4	79 ± 3	86 ± 3	84 ± 4	.30
100-d	71 ± 5	84 ± 3	83 ± 3	80 ± 5	.22
Total fetal wt, kg					
60-d	1.48 ± .09	1.20 ± .07	1.39 ± .06	1.31 ± .08	.06
100-d	6.0 ± .7	6.9 ± .5	7.4 ± .5	6.2 ± .6	.26
Avg fetal wt, g					
60-d	136 ± 4 ^a	120 ± 3 ^b	126 ± 3 ^{ab}	130 ± 4 ^a	.03
100-d	773 ± 56	632 ± 37	692 ± 36	659 ± 49	.20
Gravid uterine wt, kg					
60-d	10.9 ± 1.2	8.5 ± .8	10.0 ± .8	8.4 ± 1.0	.22
100-d	13.4 ± 1.3	15.2 ± .8	15.2 ± .8	14.3 ± 1.1	.60
Empty uterine wt, kg					
60-d	4.25 ± .34	3.41 ± .25	3.87 ± .23	3.41 ± .29	.15
100-d	4.65 ± .40	4.96 ± .27	4.99 ± .25	4.83 ± .35	.89

^{a,b}Means within a row lacking a common superscript letter differ ($P < .05$).

for each stage of gestation for comparison with fetal number and embryonal survival (Table 2), but the difference between the two stages should be due only to sampling. Therefore, ovulation rate was also analyzed ignoring stage of gestation. Meishan and Fengjing crosses had a greater ($P < .05$) ovulation rate than Minzhu or Duroc crosses. First-cross Duroc, Meishan, Fengjing, and Minzhu averaged ovulation rates of 12.1, 14.6, 15.8, and 14.3, respectively (Young, 1995a). Because of the relatively small differences in average age at puberty observed among breed types in this study, differences among breed types for ovulation rate were not likely due to the fact that ovulation rate increased after puberty with successive estrus periods (Robertson et al., 1951; Warnick et al., 1951; Paterson and Lindsay, 1980; Kunavongkrit and Larsson, 1982; Christenson, 1993).

At 60 d of gestation, there were no differences ($P = .28$) among breed groups for number of fetuses (Table 2). At 100 d of gestation, number of fetuses did not differ ($P > .05$) among the three Chinese crosses, and all three had more fetuses ($P < .05$) than Duroc

crosses. Fetal loss in late gestation in the Chinese crosses was less than in Duroc crosses. Duroc crosses averaged 3.2 fewer fetuses at 100 d than at 60 d of gestation. Fengjing and Minzhu crosses averaged only .3 fewer fetuses at 100 d than at 60 d of gestation. The sample of Meishan slaughtered at 100 d averaged 1.2 more fetuses than the sample slaughtered at 60 d. A portion of this difference must be due to sampling. Young (1995a) reported the three Chinese first-crosses did not differ significantly in number of fetuses at 60 d of gestation but had 2.9 to 3.5 more fetuses ($P < .05$) than first-cross Duroc. At 100 d of gestation, first-cross Meishan and first-cross Fengjing had significantly more fetuses than did first-cross Minzhu or first-cross Duroc.

There were no differences ($P > .05$) among breed types for percentage fetal survival at 60 or 100 d of gestation, either unadjusted or adjusted for effect of ovulation rate (Table 2). Means were adjusted to the overall mean ovulation rate of 12.8 and 12.7 for 60 and 100 d of gestation, respectively. Young (1995a) reported that breed type did not differ for fetal

Table 3. Least squares means and standard errors by breed type of gilt for reproductive traits measured from farrowing to weaning on first-parity, backcross gilts

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations	40	42	44	44	
Gestation length, d	113.3 ± .3	113.2 ± .3	113.7 ± .3	113.6 ± .3	.49
Total no. born	8.9 ± .5 ^a	10.1 ± .4 ^{ab}	10.8 ± .5 ^b	10.0 ± .5 ^{ab}	.05
No. born alive	8.5 ± .5	9.8 ± .5	9.9 ± .5	9.5 ± .5	.15
No. weaned	7.8 ± .5	8.8 ± .5	8.7 ± .5	8.6 ± .5	.50
Litter birth wt, kg	12.3 ± .6	13.1 ± .6	13.9 ± .6	12.6 ± .6	.30
Litter weaning wt, kg	53.7 ± 2.5	58.0 ± 2.4	55.2 ± 2.5	55.6 ± 2.4	.62

^{a,b}Means within a row lacking a common superscript letter differ ($P < .05$).

survival at 60 or 100 d of gestation in first-cross gilts of these breeds, regardless of whether it was adjusted for ovulation rate.

Effect of breed type approached significance for total fetal weight and was significant for average fetal weight at 60 d of gestation but was not significant for either total or average fetal weight at 100 d of gestation. Effect of breed type was not detected for gravid uterine weight or empty uterine weight. When evaluating first-crosses of these breeds, Young (1995a) reported that breed type was significant for total fetal weight and average fetal weight at 60 d of gestation and approached significance for these traits at 100 d of gestation. Young (1995a) reported that breed type effects were not detected for gravid uterine weight or empty uterine weight at 60 or 100 d of gestation.

Traits Measured on Gilts That Farrowed. Breed type did not differ ($P \approx .49$) for gestation length, and means ranged only from 113.2 to 113.7 d (Table 3). Similarly, Young (1995a) reported that gestation length did not differ among first-cross gilts of these breeds. Breed type was significant for total number of fully formed pigs born, but only the difference between Fengjing and Duroc was detected. Breed type did not differ for number born alive ($P > .15$) or number

weaned ($P > .50$), but means for Chinese crosses were very similar for these traits and averaged 1.0 to 1.4 more pigs born alive and .8 to 1.0 more pigs weaned than Duroc crosses. These differences are approximately half as large as differences among first-crosses of the breeds reported by Young (1995a). In this study, breed type was not different for litter birth weight ($P > .30$) or litter weaning weight ($P > .62$). Young (1995a) reported no significant differences among first-cross gilts of these breeds for litter birth weight and only the difference between Duroc and Meishan first-cross gilts was significant for litter weight at weaning.

Duroc-cross gilts were heavier at farrowing (d 1) and at weaning (d 28) than the Chinese-cross gilts ($P < .01$; Table 4). On d 1, Meishan-cross gilts were significantly heavier than Fengjing-cross gilts but not heavier than Minzhu-cross gilts. Breed types did not differ ($P \geq .24$) for weight change during lactation. Breed types did not differ for backfat thickness at d 1 or d 28 or for fat change during lactation. These results are consistent with differences reported by Young (1995a) for first-cross gilts of these breeds.

Results of analyses of feed efficiency during lactation and its component traits are presented in Table 5. Results for sow weight change were consistent with

Table 4. Least squares means and standard errors by breed type for sow weight and backfat thickness during lactation

Item	Least squares means and standard errors				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations	39	41	42	42	
Day-1 wt, kg	146.6 ± 2.6 ^a	140.2 ± 2.5 ^b	132.6 ± 2.7 ^c	136.6 ± 2.6 ^{bc}	<.01
Day-28 wt, kg	139.1 ± 3.1 ^a	127.9 ± 3.0 ^b	120.4 ± 3.3 ^b	123.8 ± 3.1 ^b	<.01
Weight change, kg	-7.5 ± 2.1	-12.4 ± 1.9	-12.2 ± 2.2	-12.8 ± 1.9	.24
Day-1 avg fat, mm	24.8 ± .8	26.7 ± .8	25.7 ± .9	26.2 ± .8	.36
Day-28 avg fat, mm	22.7 ± .9	24.0 ± .9	22.5 ± .9	23.1 ± .9	.58
Fat change, mm	-2.1 ± .5	-2.7 ± .5	-3.1 ± .5	-3.1 ± .5	.49

^{a,b,c,d}Means within a row lacking a common superscript letter differ ($P < .05$).

Table 5. Least squares means, standard errors, and levels of significance for effect of breed type on sow and pig performance during lactation

Item	Least squares means and standard errors				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations	35	39	38	36	
Sow weight change, kg	-6.98 ± 2.19	-12.21 ± 1.96	-12.47 ± 2.33	-12.29 ± 2.10	.25
Litter gain 0 to 14 d, kg ^a	18.8 ± .9	21.1 ± .8	20.6 ± 1.0	21.3 ± .9	.25
Litter gain 14 to 28 d, kg ^a	23.8 ± .9	25.4 ± .8	24.8 ± 1.0	25.3 ± .9	.60
Litter gain 0 to 28 d, kg ^a	42.7 ± 1.7	46.6 ± 1.5	45.4 ± 1.8	46.6 ± 1.6	.33
Sow feed consumption, kg	115 ± 3	113 ± 3	107 ± 4	115 ± 3	.31
Litter creep consumption, kg	9.0 ± 1.0	10.1 ± .9	11.4 ± 1.1	11.1 ± 1.0	.39
Megacalories of feed energy from					
Creep feed	31 ± 4	34 ± 3	39 ± 4	37 ± 3	.39
Sow feed ^b	376 ± 11	377 ± 10	355 ± 12	383 ± 11	.36
Sow weight loss ^c	54 ± 13	81 ± 12	83 ± 14	81 ± 13	.38
Total	461 ± 16	492 ± 14	477 ± 17	501 ± 15	.28
Percentage of total megacalories from					
Creep feed	6.7 ± .6	7.0 ± .6	7.9 ± .7	7.4 ± .6	.58
Sow feed	82.5 ± 2.5	77.1 ± 2.3	75.9 ± 2.7	77.5 ± 2.4	.31
Sow weight loss	10.8 ± 2.3	15.9 ± 2.1	16.1 ± 2.5	15.2 ± 2.3	.58
Litter gain 0 to 28 d/total megacalories	.0924 ± .0024	.0949 ± .0022	.0953 ± .0026	.0928 ± .0023	.66

^aIncludes only gain of pigs weaned.

^bAdjusted for feed used for sow weight gain.

^cSows that maintained or gained weight had a value of zero for this trait.

differences presented in Table 4 from the complete data set. Effects of breed type were not detected (minimum $P \geq .25$) for sow weight change, litter gain (0 to 14 d, 14 to 28 d, or 0 to 28 d), sow feed consumption (kilograms or megacalories of energy), litter creep feed consumption (kilograms or megacalories of energy), megacalories of energy from sow weight loss, or for the ratio of litter gain to total megacalories of energy.

Traits Measured on Sows Bred for Second Litters.

Breed type did not approach significance for percentage of females detected in estrus by d 8 or 30 or for average interval from weaning to first detected estrus. Differences among breed types were not detected for percentage of conception at first estrus or at first and second estrus combined or for interval from weaning to conception. Effect of breed type was also not detected for any of the litter or uterine traits measured on sows slaughtered at 100 d of gestation.

In contrast, Young (1995a) reported significant differences among first-crosses of these breeds for measurements of postweaning estrus activity and conception rate. During the first 8 d after weaning, a significantly higher percentage of Chinese first-cross than of Duroc first-cross sows were detected in estrus. Average interval from weaning to first detected estrus was significantly greater for Duroc first-crosses than for the Chinese first-crosses, which did not differ significantly. Fengjing had the shortest interval from weaning to conception, followed by Meishan, Minzhu, and Duroc. Ovulation rate of first-cross sows was highest for Fengjing, followed by Meishan, Duroc, and Minzhu; all differences were significant except for

those between adjacent means. Average fetal weight was significantly greater for Duroc first-crosses than for Chinese first-crosses. Haley et al. (1995) reported that Large White, ½ Meishan × ½ Large White, and ¼ Meishan × ¾ Large White second-parity sows had average ovulation rates of 17.2, 19.0, and 19.0, respectively, and averaged 10.6, 14.9, and 13.0 fully formed pigs per litter, respectively, when mated to Large White boars.

Lower mean litter size at second parity than at first parity for Fengjing and Minzhu females (Table 6) was consistent with data from first-cross females reported by Young (1995a). The large increase in litter size from first to second parity in the Duroc-cross females in this study is also consistent with the results on first-cross Duroc females (Young, 1995a). Haley et al. (1990) reported the difference between first- and second-parity litter size to be approximately -4, +1.5, and -8 pigs for Large White, ½ Meishan × ½ Large White, and ¼ Meishan × ¾ Large White, respectively, when bred to Large White boars. Legault and Caritez (1983), Bidanel et al. (1989), and Bidanel (1993) reported a decrease in litter size from first to second parity for Meishan, Large White, and their crosses. Other authors have reported an increase in litter size from first to second parity for purebred or crossbred Chinese females (Legault and Caritez, 1983; Wang, 1988; Christian et al., 1993).

General Discussion. Young (1995a) provided references and discussion of research published at that time on reproductive traits of purebred and first-cross Meishan relative to domestic breeds and crosses in the United States, Europe, and People's Republic of

Table 6. Least squares means and standard errors by breed type of sow for reproductive traits measured at 100 d of gestation in second-parity, backcross sows

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
Postweaning estrus					
No. of observations	40	39	43	41	
First estrus by d 8, %	69 ± 10	63 ± 9	74 ± 10	63 ± 10	.79
First estrus by d 30, %	93 ± 7	96 ± 6	92 ± 7	86 ± 7	.63
Interval to 1st estrus, d	7.8 ± 1.3	8.7 ± 1.2	7.3 ± 1.3	9.2 ± 1.3	.70
Conception					
No. of observations	37	37	38	33	
1st estrus	85 ± 6	99 ± 6	85 ± 6	91 ± 6	.24
1st and 2nd estrus	98 ± 4	100 ± 4	96 ± 4	95 ± 4	.57
Interval to conception	10.9 ± 1.8	8.9 ± 1.6	10.0 ± 1.9	10.4 ± 1.9	.83
Traits at slaughter					
No. of observations	35 ^b	37	36 ^a	31	
Ovulation rate	14.5 ± .7	15.2 ± .6	15.5 ± .7	14.0 ± .8	.36
No. of fetuses	10.5 ± .6	10.6 ± .6	9.3 ± .7	8.9 ± .7	.16
Fetal survival, %	73 ± 5	71 ± 4	63 ± 5	66 ± 5	.43
Total fetal wt, kg	8.3 ± .5	7.8 ± .4	7.5 ± .5	7.2 ± .5	.42
Avg fetal wt, kg	.805 ± .22	.763 ± .21	.809 ± .23	.823 ± .23	.15
Gravid uterine wt, kg	16.9 ± .9	15.8 ± .8	15.5 ± 1.0	14.3 ± 1.0	.24
Empty uterine wt, kg	5.53 ± .24	5.02 ± .22	5.15 ± .25	4.74 ± .26	.15

^aData were deleted for one sow that was slaughtered too early in gestation.

^bData were deleted for one sow that had a very high (40+) ovulation rate.

China. Reports were consistent in finding that Meishan and first-cross Meishan gilts reached puberty earlier and produced larger litters at birth and weaning than did domestic breeds and crosses. More recently, Haley et al. (1995) and Lee and Haley (1995) presented final analysis of their multigenerational crossbreeding study involving Meishan and Large White. Results confirm their earlier reports (Haley and Lee, 1990; Haley et al., 1990).

There are limited published results that evaluate the reproductive performance of females containing ¼ Meishan breeding. Research conducted on cooperators farms in France was reported by Gueblez et al. (1987, 1990). Over multiple parities, ½ Meishan and ¼ Meishan females averaged approximately 3 and 1 more pigs born, respectively, and 2 and .5 more pigs weaned, respectively, than Large White × Landrace females.

The following discussion includes a representative sample of the traits that differed significantly among first-cross gilts of these breeds (Young, 1995a). Only 20 to 40% of the deviation of first-cross Chinese from first-cross Duroc gilts for age at puberty and days from puberty to conception was observed when deviating ¼ Chinese from ¼ Duroc gilts. For ovulation rate, the deviation of ¼ Meishan, ¼ Fengjing, and ¼ Minzhu from ¼ Duroc was approximately 64, 41, and 18%, respectively, for gilts, and it was 44, 36, and 25%, respectively, for sows, relative to the corresponding deviations among first-cross females. Differences among ¼ breed types were 100 to 200% for number of fetuses at 100 d of gestation but -31 to 32% for number of fetuses at 60 d relative to the differences

among first-crosses. However, for number of pigs born and weaned and litter weaning weight of gilts, the deviations among ¼ breed types were near the expected value of 50% of the deviation among first-crosses. For sow weight at d 1 and 28 after farrowing, the ¼ breed types maintained 53 to 79% of the difference observed among first-crosses. Even though differences among first-cross gilts were significant for backfat at 28 d after farrowing, the differences among ¼ breed types were near zero for this trait. One-quarter breed types maintained less than 15% of the differences in ratio of kilograms of litter gain to total megacalories observed among the first-cross gilts. Differences among ¼ breed types were not consistent relative to differences among first-cross females for estrus activity or conception rate after weaning their first litter and generally retained less than expected. The interpretation is that for the ovulation rate of gilts and sows (except Minzhu), litter size and litter weaning weight of gilts and body weight after farrowing, grandmaternal effects (direct and specific heterosis), and recombination effects (specific direct and specific maternal) are relatively unimportant or are offsetting so that differences in performance of ¼ breed types for these traits can be fairly well predicted by differences among first-cross gilts. However, this was not true for age at puberty, postweaning estrus activity, backfat at d 28, or kilograms of litter gain per total megacalories consumed.

Experimental evaluation of the large number of possible crossbreeding systems that might effectively use the superior reproduction of the Meishan is not feasible. Thus, scientists in France (Bidanel et al.,

1989, 1990; Bidanel, 1993) and the United Kingdom (Haley et al., 1995; Lee and Haley, 1995) conducted experiments designed to estimate a limited number of crossbreeding parameters to predict and compare the relative merits of various crossbreeding systems. Both groups used Meishan, but from different sources, and their native Large White, which are genetically different. The experiment in the United Kingdom included purebred, first-cross, and backcross females mated to purebred boars. The experiment in France included purebred and first-cross females mated to purebred and first-cross males. The females produced were then inseminated with semen from Pietrain boars.

Results from the two experiments are very similar and indicate that the advantage in number born alive to Meishan was almost entirely maternal in origin and approximately equally divided between maternal direct and maternal heterosis effects. The estimate for maternal direct effects was 2.1 pigs from Bidanel et al. (1989) and Haley et al. (1995), and the estimates for maternal heterosis effects were 2.6 pigs from Bidanel et al. (1989) and 2.3 pigs from Haley et al. (1995).

Haley et al. (1995) reported a maternal direct effect on ovulation rate of 2.85 eggs; effects of maternal heterosis, grandmaternal direct, and grandmaternal heterosis were less than .5 eggs (absolute values). They also reported a very large maternal heterosis effect on prenatal survival (13.5%) with the next largest source of variation being grandmaternal heterosis at -3.1%.

Bidanel et al. (1989) and Lee and Haley (1995) reported that litter birth weight and litter weaning weight are largely due to heterosis effects and that maternal heterosis effects are approximately twice as large as direct heterosis effects. Both authors also reported that Meishan had positive direct additive effects but larger negative maternal additive effects on pig survival to weaning. Direct heterosis effects were larger than maternal heterosis effects on pig survival.

When averaged over first and second parity, Haley et al. (1995) reported no significant effect of direct grandmaternal effects (Meishan vs Large White) on ovulation rate, number born alive, number stillborn, number of mummies, or percentage of prenatal survival. He did report a significant positive grandmaternal heterosis effect of .49 pigs for number of stillborns for Meishan. For first parity only, the additive grandmaternal effect of Meishan was significant for ovulation rate (-1.68 eggs) and nonsignificant for number born alive (-1.08 pigs). Lee and Haley (1995) reported that neither the additive nor the heterosis effect of grandam was significant for litter weight at birth or weaning, average pig weight at birth or weaning, or for survival to weaning.

Bidanel (1993) found no decrease in the mean squared errors when epistatic effects were added to the dominance models for litter productivity traits.

Even though this would imply a lack of importance of epistatic effects, he acknowledged that levels of epistasis would have to be quite high to be detectable in his study.

Implications

Evaluation of three Chinese breeds of swine (Meishan, Fengjing, and Minzhu) indicates that use of these breeds as crossbred females could improve reproduction by decreasing age at puberty and increasing litter size of gilts. It is not clear whether use of these Chinese breeds would improve reproductive rate of sows. Given adverse effects on growth and carcass leanness, the use of Chinese breeds in commercial swine production is generally not recommended.

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