A STUDY OF PROLIFICACY AND MORTALITY AT BIRTH IN THE PIGS OF THE MASSEY AGRICULTURAL COLLEGE HERD DURING THE PERIOD 1927 TO 1941

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for the degree of Master of Agricultural Science
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INTRODUCTION.

"As an economic producer of food for human consumption the pig ranks next below the dairy cow and the laying hen. This is primarily due to the prolificacy of the porcine species. In passing, it might be mentioned that these three animals depend for their economic production upon some aspect of sexual activity. The value of the pig depends upon the prolificacy of the sow."

While accepting the fact that prolificacy is the "corner stone" of the pigs economic value, we must realise that other features such as mortality, growth rate, thrift, carcase conformation and carcase composition decide whether the prolificacy of the species realises a return commensurate with its numerical value. Further, prolificacy is as inherently variable as any other biological feature, and its variability depends not only upon genetic factors but also upon environmental influences that allow or inhibit the expression of the qualities conditioned by these factors if present.

As yet, our knowledge of the relative importance of these various environmental influences is small. At what stage in the life or reproductive cycle of the animal the various factors exercise their greatest effect, we are only slowly realising, and to these problems research must find the answer.

In this country, our stock is especially vulnerable to external conditions, and to remedy this we have two courses of action, firstly, we may insulate our animals against their environment by housing and feeding of a high order, or secondly, we may measure the effects of the environment upon the valuable features of our industry and meet these scientifically. At the present time we are not in a position to expend any great amount of finance on provision of elaborate housing, and the seasonal nature of our feed supply, together with the scarcity of cereal meals and the small proportion of our farm income derived from pigs makes it impossible, except in isolated cases, for us to provide our animals with a standard ration all the year round.

But, we can and must discover how to fit our breeding and feeding programme into the national production programme, and by research we should be able to provide the animals with the requisite conditions at the critical periods, for a full expression of their genetic capabilities.

For this reason, it is hoped that an examination of the records of a herd maintained under conditions which approximate those general throughout this country, will throw some light upon the various features of the breeding cycle which are of importance to the farmer. It is from such studies, supported by objective experiments, that the relative importance of genetic and environmental factors in determining such features as, number of pigs born, and the incidence of mortality at birth, will eventually be determined.

Further, farming conditions in this country in relation to pig production are peculiar to New Zealand and probably parts of Australia, and comparison of results obtained here with those overseas is of interest, not only as a check on conclusions drawn from limited numbers, but also from the viewpoint of general practise in that the data from such countries as Denmark may be regarded in the light of control experiments on a national scale.

SOURCE OF DATA.

The data used in this investigation were obtained from the records kept of the Massey Agricultural pig herd. The conditions under which the animals are maintained may be regarded as fairly representative of those obtaining in the better conducted commercial herds in this country, and any conclusions that have been arrived at in the course of the study are probably generally applicable.

The herd, since its inception in 1927 has undergone many changes, both in breeds kept and in general feeding and management, and therefore an outline of the salient points in its short history may be regarded as important.

When first instituted the herd was composed of Large Whites, Large Blacks, Berkshires and Tamworths. By 1932 only Large Whites and Tamworths remained, and in the Spring of 1935 the stud was devoted entirely to the latter breed, a condition which was maintained until 1939 when Large Whites were once again introduced.

A change in general policy has also been brought about in the management in that while the herd has been, in the past, kept as a stud, since the Autumn of 1938 sales of breeding stock have been incidental and secondary in importance to the experimental programme which was planned about that time.

The housing and layout of the piggery has also undergone a radical change. Prior to 1932 the Waikato type of house and yard was used but this was then changed to the present Manawatu type. Until this time a permenant pigman was employed, but from 1932 until 1937 the work was done as part of the ordinary farm routine.

Whey has been the most used dairy by-product except in the 1939/40 season when skim milk was purchased and during week-ends when this product was available from the College dairy. Meal feeding has always been practised, but since 1931 the quantity fed has been somewhat reduced.

The present animals can be traced to three foundation sows, one of which, Wallongbar Twilight was imported to this country from Australia together with a boar Hawkesbury Exeter. While three sows may be said to be the foundation animals their blood lines have not been developed separately and so no distinct strains have been bred.

The number of sows in the herd at any one time varies, somewhat, but the average is in the vicinity of 12-16. The records comprise service and farrowing dates, the numbers born alive and dead and their sex. Unfortunately no record has been kept of weights of sows during suckling or gestation and new-born pigs are not weighed. As is generally done in this country sows are run on pasture and receive some supplementary feed while pregnant and are brought into the farrowing houses about a fortnight before due, but this rule may be broken if farrowings are frequent and accomodation is overtaxed at any one time.

Because of the changes in manangement, in breeds kept, and in numbers constituting the herd the data were useful only from 1935 on for most considerations, since only from this date has the Tamworth stud assumed proportions sufficient for critical analysis.

TREATMENT OF DATA.

In arranging the data to be treated, a breeding chart was prepared which summarised information relating to farrowing dates, sire and litter particulars such as sex and still-births. A modified card index was employed, the cards used being those prepared for use in dairy records. Wherever possible, the analysis of variance described by Snedecor (11 - 15) was used to allow for disproportionate subclass numbers.

The small number of observations possible has made the use of unequal class numbers unavoidable in most cases, since the elimination of data would have produced classes of such small size that treatment would have yielded entirely undependable results.

When appropriate correlation coefficients have been calculated between variables according to Snedecor (7 - 2).

Some doubt exists as to whether litter size can be regarded as measurement data, therefore, where an analysis of variance has been applied to this variable - the chi-square test has also been employed. Where but two attributes - such as maleness and femaleness are considered the chi-square test only has been used.

S E C T I O N   I.

LENGTH OF GESTATION PERIOD AND FACTORS AFFECTING IT.

In this study the gestation periods of 68 sows farrowing, in all, 189 litters, were available. The average length of pregnancy was 113.175 $\pm$ 2.03 days. As shown by Figure I the range was fairly wide, 105 to 122 days for sows farrowing normally. Two farrowings of 127 and 132 days were recorded, but both litters were born dead and so were not included in the data.

Discussion.

Dassogno (1916) states that the usual length of the gestation period of the 176 cases studied by him in the York-shire breed, was 111 to 116 days with extremes of 106 and 128 and a mean of 114 days. Sinclair and Syratuck (1928) working with the records of 278 sows found the mean period of pregnancy to be 114.6 days, but gives no indication of the range of variation encountered, while Johansson (1928), McKenzie (1930), Schmidt, Lauprecht and Staubesand (1936), Husby (1933), Krizenecky (1937) and (1938) report mean periods of essentially similar length which are summarised in Table I.

Figure I

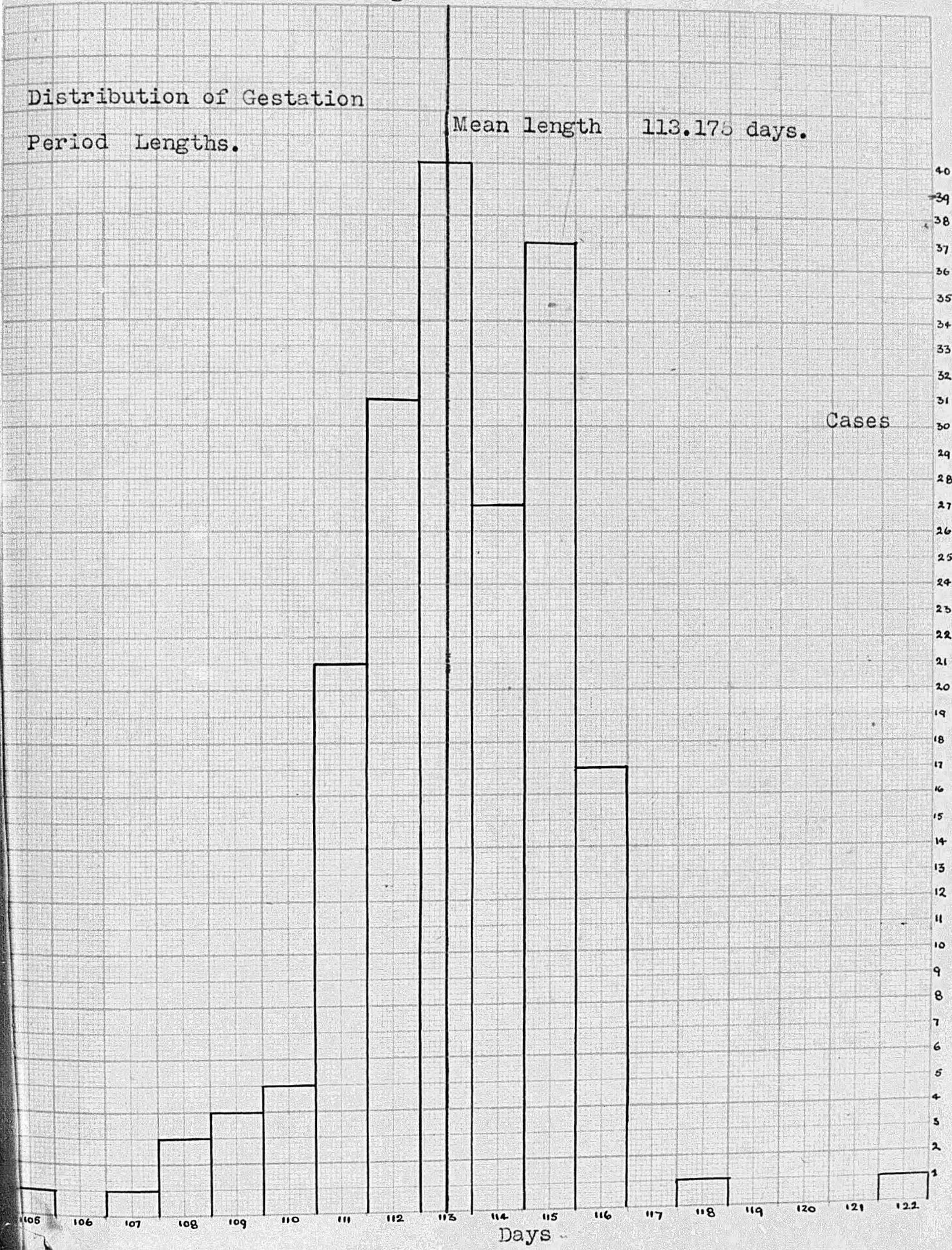

Distribution of Gestation
Period Lengths.
Mean length 113.175 days.
Cases
Days
105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Table I.

The number of cases studied, the range and the mean length of gestation periods reported by various workers.

Authority	Breed	Cases	Mean	Range
Dassogno.	Y.	176	114.0	106-128
Sinclair and Syratuck.		278	114.6	
Johansson.	Y.	1423	114.3	105-124
Husby.			113.1	
Schmidt, et alia		337	112-115	
McKenzie.			113.5	
Krizenecky.		357	114.55	
"		1080	81% in range 113-117	
Carmichael and Rice.	B.	293	115.4	
	C.W.	30	113.0	
	D.J.	62	113.1	
	H.	2	112.5	
	P.C.	48	114.6	
	T.	32	113.8	
	Y.	30	113.2	

Y. - Large Yorkshire

B. - Berkshire

C.W.- Chester White

D.J.- Duroc Jersey

H. Hampshire

P.C.- Poland China

T. - Tamworth

It is evident that the range of means is only 112-115 days, and that the mean length of gestation period observed in the sows of the College herd does not differ greatly from that recorded in sows elsewhere. It may be noted here that in no case has the literature studied made any reference to the method of measuring the duration of pregnancy. When it is considered that the period of oestrus for the sow lasts about three days, that the sow may be mated on any one or all of these days, and anyone of these matings may be regarded as successful by the recorder, then it is obvious that a certain error may creep in and unless records are standardised a discrepancy among results is to be expected.

In the College herd the sow is usually mated on the second day of heat and the record dates from the day of service to and including the day of farrowing.

A further source of variability may well be that due to differences between breeds. Carmichael and Rice (1920) suggest that Berkshires carry their young appreciably longer than other breeds, but the number of periods studied by them in animals other than Berkshires is so small that this conclusion may be open to question. This borne out in this case by the fact that these workers quote 113.2 days as the mean for the Large Yorkshire breed when treating only thirty cases, while Johansson and Dassogno quote 114.0 and 114.6 days respectively when dealing with much greater numbers in the same breed. Unfortunately, the only source of reference for the work of many of these investigators consisted of abstracts in which mention was only sometimes made of the breeds treated, and so a detailed study of possible breed differences becomes impossible.

FACTORS INFLUENCING THE LENGTH OF THE GESTATION PERIOD.

1. Ratio of sexes.

No evidence could be gained from a study of the ratio of sexes within litters of sows of the College herd that this factor influenced the length of the gestation period. The number of males in each litter was expressed as a percentage of the total number of pigs born in the litter, and within the resulting range, class intervals were arranged.

Table II.

The influence of the sex of the pigs born upon the length of the gestation period.

% Males.	No. of cases.	Mean length/gestation period.
0-10%	2	114.0
10-20	4	112.7
20-30	11	113.9
30-40	17	112.4
40-50	40	113.1
50-60	38	113.8
60-70	39	112.5
70-80	13	114.0
80-90	3	113.6

From the Table it would seem immaterial whether males or females are in excess in regard to the effect upon the length of pregnancy experienced by the sow bearing the litter.

Discussion.

Dassogno (1916) states that the excess of one sex does not alter the length of the period, but Krizenecky (1937), on the other hand, states that a high proportion of males seems to have the effect of lengthening the pregnancy period. The abstract of Krizenecky's work does not record the pro--portion of males which results in this lengthening of the time the litter is carried, nor does it supply any information as to the magnitude of the differences.

While it is fairly well established that the gestation periods of cattle are, on the average, lengthened by one or two days by the bearing of male calves, it is a matter of some conjecture whether or not the presence in utero of numbers of male and female foeti at the same time would not modify the conditioning effect upon time of parturition exercised by hormone secretions. However, the true nature of the physiological significance of delayed parturition in animals normally giving birth to single offspring, must needs be understood before the knowlege can be applied to the necessarily delicate balance in the sow where, in the majority of cases, males and females are born in the same farrow.

2. Size of litter.

Dassogno (1916) states that the number of pigs born in any litter does not affect the length of the gestation period, and this opinion is shared by Johansson (1928), Schmidt et alia (1936), McKenzie (1930) and Krizenecky (1935). On the other hand Carmichael and Rice (1920) found that some of the litters which were carried longer than the average, were smaller than those which were farrowed earlier than the average.

The data from the College herd are presented in Table III.

Table III.

The mean number born in litters grouped according to the length of the gestation period.

No. cases.	Gestation period (days).									
	107	108	109	110	111	112	113	114	115	116
No. cases.	1	4	4	5	22	30	44	24	36	17
Total pigs born.	9	39	31	54	204	258	372	167	268	152
Mean litter size.	9.0.	9.75	7.75	10.8	9.3	8.6	8.4	6.9	7.4	8.9

It would appear from this Table that the larger litters were born following a short gestation period, and so a further analysis was carried out.

Table IV.

The mean lengths of gestation periods grouped according to litter size.

Litter size.	No. cases.	Mean length of gest/period
3.	9	114.11
4.	7	114.14
5.	10	114.0
6.	19	112.73
7.	22	113.68
8.	19	112.42
9.	31	113.32
10.	24	113.54
11.	18	112.0
12.	13	113.3
13.	3	112.0
14.	6	112.8
15.	3	109.3

An analysis of variance was carried out on these data.

The result was:

Source of V.	d.f.	s.s.	m.s.
Total	183	673	
Between litter size groups	12	116	9.66xxx
Within " " "	171	557	3.25

F = 9.66/3.25
= 2.97xxx
d.f.= 12:171
F at the 1% pt= 2.30

The result is highly significant.

It would seem therefore, that large litters are carried <u>in utero</u> for a shorter period than smaller ones, if the limited number of cases available may be regarded as representative of a general condition. No explanation can be offered as to why these results should differ so markedly from those of other workers.

3. Age of sow.

Dassogno (1916) states that length of gestation period varies with age, and his conclusions are supported by Johansson (1928). McKenzie (1930) and Sinclair and Syratuck (1928) hold the opposite view and state that the age of the sow appears to have no effect on the length of pregnancy.

Table V. summarises the position in regard to the herd examined.

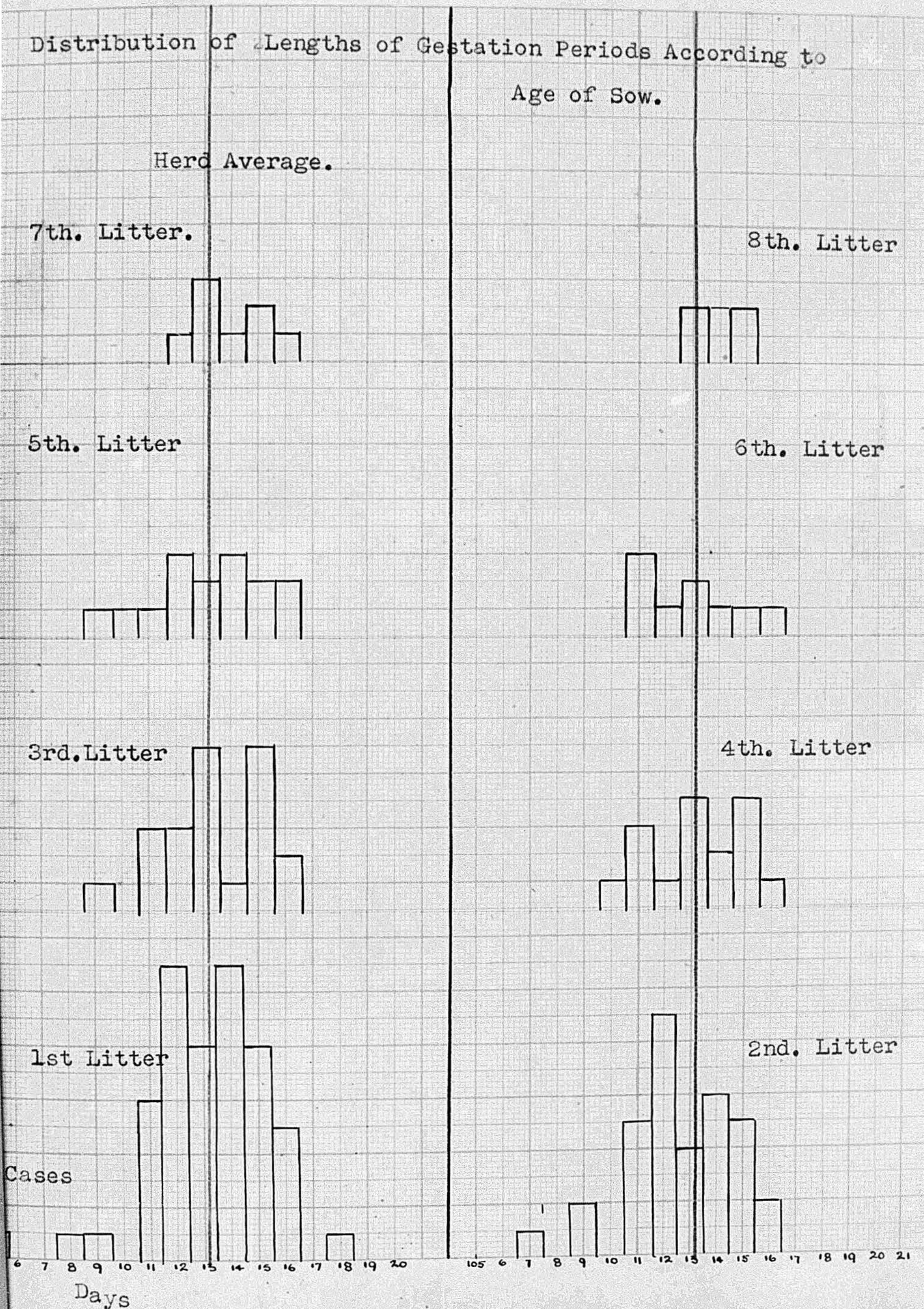
Table V.

Length of gestation period in relation to age of sow expressed in consecutive litters.

Litter No.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Cases.	54	35	26	16	15	9	8	6	4
Means.	113.0	112.6	113.2	113.2	113.1	112.9	113.9	114.0	112.0

The range of variation is presented in Figure 2. Litters 1-6 exhibit a very similar range, while litters 7-8 tend to be a little more asymetrical toward the higher values. The limited number of cases observed in the latter two,

Figure II



Distribution of Lengths of Gestation Periods According to Age of Sow.
Herd Average.
7th. Litter.
8th. Litter
5th. Litter
6th. Litter
3rd. Litter
4th. Litter
1st Litter
2nd. Litter
Cases
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
105 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days

however, does not allow for any conclusions to be drawn. It would seem from the data presented that there is little or no tendency for advancing age to be accompanied by any constant increase in the length of gestation period in the case of the herd studied.

4. Effect of season of farrow.

Johansson (1928), Schmidt et alia (1936) and Carmichael and Rice (1920) have found that the season of farrow exerts no significant influence upon the length of the gestation period. Data from the College herd support this conclusion.

Table VI.

The influence of season of farrow upon the length of the gestation period.

Years.	Seasons. Dec/March	Apr/July	Aug/Nov.
1934/5	113.0	114.0	114.7
1935/6	114.6	113.0	114.7
1936/7	112.7	115.0	113.2
1937/8	114.2	111.8	113.3
1938/9	113.0	112.1	112.0
1939/40	112.8	112.5	113.0

These data were examined by an analysis of variance and a non-significant result was obtained.

The weight of evidence seems to point quite definately to the fact that this factor does not influence the length of the gestation period.

OTHER FACTORS INFLUENCING THE LENGTH OF THE GESTATION PERIOD.

Dassogno states that the condition of the sow has an effect upon the length of pregnancy, but McKenzie does not agree that the plane of nutrition exerts any effect. It is not stated by either worker as to what stage of gestation their criteria refer, and further, the terms can hardly be regarded as synonymous. The time over which the plane of nutrition was held would, of course, determine the condition of the sow.

The correlation between the length of pregnancy and the birth weight of the pigs born has been studied by Dassogno (1916), Carmichael and Rice (1920) and Krizenecky (1935) but no significant values were found. Since litter weight at birth is not recorded in the College piggery no data could be collected on this point.

To summarise, therefore, while results obtained are dependant upon very limited data, it would seem that:

1. Gestation periods in the College herd are comparable with those recorded eleswhere in regard to length of duration.
2. Neither the sex ratio of the offspring, the age of the sow, nor the season of farrow appears to be correlated with changes in the length of pregnancy.
3. The size of the litter farrowed does seem to bear a direct relationship with the length of the gestation period.

SECTION II.

THE INFLUENCE OF THE INTERVAL BETWEEN GESTATION PERIODS UPON SUBSEQUENT LITTER SIZE.

Since first litters must be excluded from a study of this nature, the numbers available for treatment were small, only 120 cases fulfilling the necessary conditions. These were arranged in class intervals of one week starting with six weeks as a base.

Management in the College herd involves the weaning of litters at eight weeks of age and so any mating taking place within the period of eight weeks subsequent to parturition involves mating of suckling sows. A limited number of such cases were available but the data relate, for the most part, to matings made subsequent to the weaning of litters.

Table VII.

Mean litter size in relation to the interval between successive gestation periods.

Class interval.	No. litters.	Pigs born.	Mean litter size.
6-7 weeks	4	26	6.5
7-8 "	6	61	10.16
8-9 "	51	442	8.66
9-10 "	20	182	9.10
10-11 "	15	160	10.66
11-12 "	10	79	7.90
12-13 "	7	60	8.57
over 13 "	7	61	8.71

This range of values does not in itself, mean very much, on account of the small numbers in any one class, so class intervals were combined in series according to possible influences. In view of the fairly widely held opinion that the practice of mating sows during lactation is wrong in that it imposes too great a strain on the sow and might effect not only the weaning weight of the litter then suckling, but also the size of the litter resulting from the mating, the class intervals of 6-7 and 7-8 weeks were combined in class one.

Again, it is maintained by officers of the New Zealand Department of Agriculture that, subsequent to weaning a litter, the unused milk in the mammary glands is resorbed into the blood-stream causing a flushing effect similar to that desired in ewes at tupping time. If such be the case, it is a matter of some conjecture as to how long this "flushing" effect will last. If a sow, having been taken from her litter fails to show any signs of "heat" within any arbitrary period, such as three weeks, does the toning effect of the milk resorption persist long enough to exercise any measurable influence on the shedding of ova subsequent to this interval?

If resorption of the unused milk does have any physiological significance, it is possible that its effect would be to hasten the migration of follicles to the surface of the ovary and even increase the number of such ripe follicles.

Since no appreciable work seems to have been done on this subject, it was felt that the most satisfactory method of deciding upon the series to be included in this hypothetically most advantageous period, was to set a limit of three weeks. By this method any sow which has more than an eleven weeks service period, or is mated three weeks after weaning, will probably have progressed beyond the time when flushing due to milk resorption could be effective, and further, any sow mated or merely "on heat" within this period would be unlikely to experience oestrus a second time within the same period.

Table VIII.

The influence of the interval between gestation periods upon litter size.

	Class intervals.		
	6-8 weeks.	8-11 weeks.	11 weeks & over.
No. pigs born.	87	784	200
No. of litters.	10	86	24
Mean litter size.	8.7	9.1	8.3

These data were treated by an analysis of variance and a non significant result was obtained.

It is noteworthy that, in the class, 11 weeks and over, several cases of extremely long intervals were found, namely, 16, 21, 22, 28 and 36 weeks. The litter sizes in these cases were 10, 3, 11, and 9. While the numbers are small it is evident that though such animals persistantly fail to conceive in successive matings due probably to some health factor either physiological or pathological, or to a sow being deliberately held back from service, yet when mating is at last successful, litter size does not seem to have been adversely affected.

Rather surprisingly, sows mated while still lactating did not, as a class, exhibit a mean litter size as low as sows mated three weeks after weaning. Within the weekly class intervals of Table VIII a distinct difference can be observed between sows mated six weeks after farrowing and those mated seven weeks after farrowing. These cases were examined further to discover, if possible, the reasons for the observed difference, and the circumstances of such matings.

The sows mated in the sixth week of lactation were found to have weaned, in litters suckling at the time of mating, an average of 4.25 pigs per litter with a mean litter weight of 176 pounds. The actual weights and numbers weaned for each sow are presented in Table IX As a further means of comparison the average number of pigs born per litter in all litters excluding the particular litter under consideration, is set out for each sow.

Table IX.

Size of litter weaned, litter weaning weight, and mean weaning weight per pig for litters suckled at the time of mating and number of pigs farrowed as a result of this mating, compared with the mean number of pigs born in all other litters for individual sows.

(Table IX over page)

	Sows.			
	1.	2.	3.	4.
Litter weight	89	307	141	166
No. weaned.	2	8	3	4
Mean per pig.	44.5	38.4	47.0	41.5
No. next litter.	6	10	9	1
Average born in all other litters.	4.5	10.2	5.5	9.0

It would seem that the production of one pig by sow 4. in the farrowing under consideration was exceptional. As a result, it is wise to consider only the first three sows, with a mean litter size subsequent to the six weeks interval between gestations of 8.3 pigs.

Despite the lamentably small class treated, it is evi--dent that the effect of mating during lactation has not greatly influenced the size of litter produced in the subsequent farrowing, and in the case of the sows mated in the seventh week of lactation no effect is apparent, If sow 4. is included, a real difference becomes apparent, but such evidence is hardly acceptable.

As shown in Table IX , the number of pigs weaned in the litters suckling the sow at the time of mating are relatively small, and also, that whereas the litter weaning weights are low in three out of the four cases, the average weight per pig within each litter is very high, ranging from 38 to 47 pounds.

It is reasonable to assume, therefore, that mating, as carried out, was done because the number to be weaned was small and the piglets were already satisfactorily grown. This does not apply to sow 2 and no attempt is made to explain the situation.

Discussion.

The possible influence of the interval between gestations does not seem to have been subject to any serious attempts at investigation. Krizenecky (1935) states that litter size is not related to the interval between farrowings, and Buchanan Smith (1936) mentions that there is some conflicting evidence to the effect that such intervals have little influence upon subsequent litter size.

It may be concluded, tentatively at least, because of the smallness of numbers treated here, that in the College herd, the interval between gestations has no effect upon litter size in subsequent farrowings.

THE RELATION OF SIZE OF LITTER TO THE AGE OF THE DAM.

In the course of this study data relating to 66 sows farrowing 199 litters were examined. At the outset difficulty was experienced in interpreting the data because of the lack of continuity existing in the records of individual sows. Whereas 66 sows farrowed one litter while in the herd, only 6 sows farrowed 8 litters. It became obvious that selection of some sort accounted for this reduction in numbers with increasing age and no true interpretation of the effect of age could be made unless this factor was allowed for.

The fact that selection was spread over a number of years is also a complicating factor when dealing with the data from the point of view of age alone, since standards for selection are necessarily dependent upon the material available in any one year, and the phenotypic expression of prolificacy at any time is conditioned so greatly by environment which varies considerably from year to year. However, it should be possible to find out whether the effect of any selection has been toward larger litters, even with the data for various years grouped together.

It is realised, that in any herd, selection can seldom, if ever, be based upon litter size alone. Equally important to the big producer are such factors as the number of pigs born alive, and weaned; the weaning weight of the litter, the variability, thrift and conformation, for such things are to the farmer, the only measures by which he can judge the prolificacy, milking ability, mothering ability and constitution of his sows. However, for this study, it is immaterial what the reason for the culling of any sow might have been, except in so far as that culling has produced an effect upon the average of the remaining sows.

That selection may well have been based upon number born, number weaned, or weaning weight may be seen from Table X, where non-cull sows are invariably superior to the appropriate group of cull sows in their performance.

Table X.

Comparison of means of; Number born per. litter; Number born alive per. litter; Number weaned per. litter; and Weaning weights per. litter, of litters from cull sows (1) and non cull sows (2)

1 Litter class.

	No Born 1	No Born 2	Born alive 1	Born alive 2	Weaned 1	Weaned 2	Weaning wt. Per. Litter. 1	Weaning wt. Per. Litter. 2
1	6.8	7.6	5.9	6.9	4.5	5.8	145	201

2 Litter class.

	No Born 1	No Born 2	Born alive 1	Born alive 2	Weaned 1	Weaned 2	Weaning wt. Per. Litter. 1	Weaning wt. Per. Litter. 2
1	7.6	7.5	6.5	7.0	5.4	5.9	176	211
2	5.5	7.9	5.0	7.2	4.2	6.2	142	242

3 Litter class.

	No Born 1	No Born 2	Born alive 1	Born alive 2	Weaned 1	Weaned 2	Weaning wt. Per. Litter. 1	Weaning wt. Per. Litter. 2
1	6.7	7.6	6.6	6.9	6.3	6.3	216	257
2	8.6	7.4	7.9	6.5	5.7	6.0	227	249
3	9.4	9.2	7.5	8.3	7.1	7.2	262	275

Table X. (Cont.)

4 Litter class.

	No Born		Born alive		Weaned		Weaning wt. per Litter	
	1	2	1	2	1	2	1	2
1	6.0	8.0	5.8	7.5	4.6	6.3	187	226
2	6.0	7.8	5.6	7.3	4.8	6.6	205	276
3	6.7	9.9	5.6	9.1	4.8	7.8	204	298
4	8.5	9.2	6.6	7.9	6.2	7.1	197	299

5 Litter class.

	No Born		Born alive		Weaned		Weaning wt. per Litter	
	1	2	1	2	1	2	1	2
1	8.0		7.3		6.7		228	
2	8.5		8.0		8.0		327	
3	10.5	9.9	9.0	9.5	6.2	7.7	205	
4	8.2	9.3	7.5	8.4	6.5	7.5	269	341
5	10.5	8.9	8.7	6.7	8.0	6.0	248	246

6 Litter class.

	No Born		Born alive		Weaned		Weaning wt. per Litter	
	1	2	1	2	1	2	1	2
1	8.0		8.0		2.5		108	
2	5.3		4.5		2.5		108	
3	9.0		7.5		6.0		205	
4	10.3	9.2	8.6	8.7	6.5	7.7	302	349
5	10.3	8.5	8.3	6.4	6.5	5.9	250	245
6	6.3	9.1	4.6	7.1	1.5	6.5	186	274

The numbers culled from each litter class are as follows:-

(1) 23, (2) 13, (3) 10, (4) 5, (5) 4, (6) 3, (7) 2.

In order to present the position in regard to the effect of selection upon litter size - Table XI. was prepared. In this table, the term "litter class" refers to the age of the sows concerned, expressed in terms of the number of litters farrowed. Thus sows that had farrowed 4 litters are placed in the 4 litter class.

Table XI.

Comparison between mean litter size of sows culled, retained, and the mean of all sows of that litter class, in litter classes 1 - 8.

	Mean for all Sows.	For sows culled.	Sows Retained.
		1 Litter class.	
1	7.4	6.6	7.6
		2 Litter class.	
1	7.6	7.6	7.6
2	7.6	5.5	7.9
		3 Litter class.	
1	7.5	6.7	7.6
2	7.8	8.6	7.4
3	9.3	9.4	9.2
		4 Litter class.	
1	7.6	6.0	8.0
2	7.4	6.0	7.8
3	9.5	6.7	9.9
4	9.0	8.5	9.2
		5 Litter class.	
1	8.0	8.0	8.2
2	7.8	8.5	7.7
3	9.9	10.5	9.7
4	9.2	8.2	9.5
5	9.4	10.5	9.0
		6 Litter class.	
1	8.2	8.0	8.3
2	7.7	5.3	8.6
3	9.7	9.0	10.25
4	9.5	10.3	9.2
5	9.0	10.3	8.5
6	8.3	6.3	9.1
		7 Litter class.	
1	8.30	7.5	8.5
2	8.3	5.5	9.6
3	10.25	8.5	10.8
4	9.20	8.5	9.5
5	8.5	8.5	8.5
6	9.1	10.5	8.7
7	8.6	7.5	9.0

It may be seen from Table XI. that the culling of sows has resulted in an increase in the over-all average of the sows selected to remain in the herd.

There are two exceptions to this, however, the 3 litter class and the 5 litter class. As a result neither the 4 litter class nor the 6 litter class may be regarded as the result of immediate selection on litter size. It is a question therefore, just what classes may be included in the final consideration, and it was decided to include the 6, 7 and 8 litter classes only. This was done because on examining the last litters of sows culled in the last two classes in the table it was found that litter size had fallen sharply, in these cases, therefore, it may be reasoned that, sows at this age tend to fall somewhat in production and are naturally eliminated to maintain the herd average. This masks a fall in production beyond the sixth litter but if it is recognised that this fall does take place, then the retention for study of the last two classes in the table and the 8 litter class as well, can be justified. Selection may therefore be broadly classed for this consideration upon two separate effects. The selection for litter size in the lower litter classes tends to accelerate unnaturally any rise in production with age, and selection in litter classes beyond the fifth tends to sustain the level of production in spite of age.

The average litter size of the sows in the 6, 7 and 8 litter classes are presented in Table XII.

Table XII.

The influence of age upon litter size.
(Sows which have farrowed 6 - 8 litters.)

	Litter No. 1	2	3	4	5	6	7	8
Mean Litter Size.	8.2	7.7	9.7	9.5	9.0	8.3	8.6	9.0
No. Cases.	11	11	11	11	11	11	8	6

These data were treated by an analysis of variance and a non-significant result was obtained.

It would appear, therefore, that when due account is taken of the effect of selection, age exercises no significant effect upon litter size. However, this must be qualified, since, by eliminating the effect of selection, the litter classes remaining are only those which were originally sufficiently high producers to maintain their position in the herd. These sows may have produced such large litters at an early age that no great increase was possible to them with succeeding litters. Further, the small number of sows remaining to be treated when allowance is made for the effect of selection means that the rise observed in Table XII up to the third litter may be real, but impossible to prove statistically.

In relation to further treatment of data from the herd in later sections of this thesis, when all litters must be considered, it was decided to carry out an analysis of variance on all data.

Table XIII

The influence of age and selection upon litter size.

	Litter No.							
	1	2	3	4	5	6	7	8
No. Litters.	66	43	30	20	15	11	8	6
No. Pigs born.	508	343	280	183	141	92	69	55
Mean Litter Size.	7.7	7.9	9.3	9.1	9.4	8.4	8.6	9.2

The result of the analysis of variance was again non-significant, the variation between age groups being less than that within.

Results of Other Workers.

Machens (1918) and Scott (1938) suggest that maximum litter size is reached in the fourth litter, while Sinclair and Syratuck (1928), Zorn, Krallinger, and Schott (1933), and Ostermayer (1934) consider that the sixth litter marks the maximum. These latter workers are in fairly close agreement with Keith (1930) who gives 4½ years as the most prolific age, and Hetzer et alia (1940) who report an increase in litter size up to 3½ years - which maximum is held until 5½ years. On the other hand Krizenecky (1937) states that the second litter is the largest. Husby (1933) is content to express the opinion that adult sows are more fertile than gilts.

Apart from Keith, however, none of these workers appear to have taken any account of the effect of selection. Sinclair and Syratuck for example treat 101 yearling sows and only 15 five-year-old sows.

Ellinger (1922) and Eckstaedt (1928), however, have made allowance for this factor. Ellinger worked on data relating to sows on which there were records for ten litters, and Eckstaedt, sows that were retained in the herd over a period of time. The result of this work is that Ellinger asserts that litter size increased up to the 7th. or 8th. litter and then decreased slightly, while Eckstaedt found the effect of age on litter size was small.

The weight of opinion seems, therefore, to be that the maximum litter size is reached by sows farrowing their 6th. or 7th. litter, while, in those cases when selection was allowed for, one opinion is in favour of a gradual increase up to the 7th. or 8th. litter and one of a negligible increase. The results are summarised in Table XIV.

Table XIV.

Summary of results regarding the effect of age on litter size.

Authority.	Age or litter number when maximum reached.	Whether selection allowed for.
Ellinger	7 - 8th. litter	All sows produced 10 litters.
Eckstaedt.	Effect small	Only sows in herd for long time.
Keith	4½ years	Eliminated all sows having only 1 litter
Krizenecky	2nd Litter	Not mentioned.
Sinclair & Syratuck	6 - 7th. litter	" "

Table XIV (Cont.)

Ostermayer	6th litter	Not mentioned
Zorn et alia	6th litter	" "
Scott	4 - 5th litter	" "
Morris and Johnson	5 years	" "
Hetzer et alia	$3\frac{1}{2}$ - $5\frac{1}{2}$ years	" "
Husby	Adult sows more fertile than gilts	" "
College herd	2nd. litter - but effect non-sig.	Selection recorded.

Keith, by eliminating all sows which farrowed but one litter, did away with a certain amount of the effect of selection, but in view of the data presented here on the College herd, this measure can hardly be regarded as sufficient.

If it were safe to assume that Ellinger and Eckstaedt were the only workers among those cited who had given due consideration to the influence of selection on litter size, one can only conclude that, as a factor, age has received more than its due of credit among factors influencing litter size.

THE INFLUENCE OF SEASON OF MATING AND FARROWING ON LITTER SIZE.

Under New Zealand conditions of management, pigs are subject to considerable seasonal changes in environment, as a consequence of the prevailing open air husbandry and the seasonal nature of dairy by-product supplies which constitute the main feeding stuffs. In the College herd environmental influences are probably less extreme than in the average commercial herd, but nevertheless, there are wide differences between summer and winter conditions. For this reason it was considered important to study the possible effect of season, through variations in food supply and weather conditions, on the breeding performance of sows.

Since, if there is any effect upon litter size of these factors according to season of mating and season of farrow, this effect may be fairly safely attributed to the incidence of the same factors in varying degrees of intensity at different stages of pregnancy in the sows under consideration, therefore it is felt that a more complete picture of the possible influence of these factors can be presented by the consideration of the two together.

The data of service and farrowing dates were divided into three classes of four monthly intervals. The division was such that the effects of optimum temperature and feed conditions could be compared with the most disadvantageous conditions in these respects, and a third period, in which the factors might approach either of the above conditions depending largely upon the conditions pertaining to any year.

The periods were: 1, December to March (inclusive); 2, April to July (inclusive); 3, August to November (inclusive).

It is realised that, a more precise method would have been to make the division of three monthly intervals in which case the measure would have been more delicate. However, the rather limited number of sows available made this impossible.

Only sows having at least two litters were treated because it was reasoned that by this method the variation due to sow individuality would in some measure be allowed for in that this individuality was exerted in at least two different seasons. In regard to the first litters of all sows, it was felt that, despite the previous negative findings in respect of age on litter size, the inclusion of unequal numbers of such litters in the three periods might exert an effect. On examination of these cases it was found that in four years out of six in the April to July period the mean was increased as a result of the presence of first litter sows. In both of the other two periods in all cases the mean was lowered by the inclusion of first litters. In view of the results obtained this masks rather than accentuates the seasonal differences and so no correction was felt to be necessary.

The mean litter size for the three periods of mating according to year are recorded in Table XV.

TABLE XV.

The influence of season of mating in years 1935 - 1940 upon the number of pigs born per litter.

Period. 1. December to March (inclusive)

2. April to July (inclusive)

3. August to November (inclusive)

	Season. 1.	2.	3.
Year.			
1935	13.0	7.5	8.0
36	8.62	8.0	8.66
37	11.5	6.5	8.11
38	8.5	7.8	7.6
39	9.0	8.6	8.4
40	8.31	8.33	9.28
Means for	9.1	7.7	8.32

Though, on the whole, Period 1 matings tend to produce larger litters than matings in the other two periods, there are considerable annual fluctuations for any one period while from one year to another differences between periods vary considerably.

These differences may possibly be due to an expecially cold winter, late spring or dry summer conditions in any year influencing one period to a greater or lesser degree than another.

The data above were treated according to X^2 technique.

This method involves the use of equal class numbers, and to satisfy this condition the number of litters in the three classes was reduced to that of the smallest, namely 39. This reduction was achieved by random selection of litters from classes 2 and 3.

The computations are set out in Table XVI.

Table XVI.

Total pigs born in 39 litters in seasons 1, 2, and 3.

	1.	2.	3.
	355	296	330
No. of litters	39	39	39

$$Sx^2 = SX^2 - (SX)^2/n = (355)^2 + (296)^2 + (330)^2 - (981)^2/3.$$

$$= 322,541 - 320,787$$

$$Sx^2/\bar{x} = 1754/\bar{x}$$

$$= 1754/327$$

$$= 5.363$$

P at 5% point $= 5.991$

Since the value of chi-square for the three seasons was found to fall just short of significance a computation was made between combinations of pairs of seasons as set out in Table XVII.

Table XVII.

Computation of X^2 between the number of pigs born in the three periods, arranged in groups of two.

Periods

1.	2.
355	296

$$Sx^2 = SX^2 - (SX)^2/n$$
$$= 213.641 - 211,900$$
$$= 1741$$

$$Sx^2/\bar{x} = 1741/325$$
$$= 5.3$$

P at the 5% point = 3.841

Periods

1.	3.
355	330

$$Sx^2 = SX^2 - (SX)^2/n$$
$$= 234,925 - 234,612$$
$$= 313$$

$$Sx^2/\bar{x} = 313/342$$
$$= .91$$

Periods

3.	2.
330	296

$$Sx^2 = SX^2 - (SX)^2/n$$
$$= 196,516 - 195,938$$
$$= 578$$

$$Sx^2/\bar{x} = 578/313$$
$$= 1.85$$

From the values of chi-square above it would appear that December to March matings are significantly superior to the April to July matings in regard to the number of pigs born at the subsequent farrowings, but the August to November matings are not significantly superior to the April to July matings.

However, the mathematical reservations of the chi-square technique do not allow for a comparison between mating periods, within years and within mating periods, and so an analysis of variance was applied. It is realised that such an analysis is open to challenge on the score that the number of pigs in a litter may be regarded merely as enumeration data, rather than measurement data.

A possible alternative would be to endeavour to establish a correlation or regression coefficient between such measures as size of litter and total weaning weights of litters and by using weaning weights as a measure of seasonal influences apply the regression coefficient to arrive at the effect of season of mating on litter size, with due allowance having been made for mortality. To achieve such a technique, however, ample data must be available and with the small number of animals treated it is felt that the accuracy of such a method would be no less open to challenge than the simple analysis of variance. It may be mentioned that Ellinger (1922) considers litter size as capable of being treated as a continuous variable. Results of the analysis are presented in Table XVIII.

Table XVIII

Analysis of variance on the effect of season of mating sows upon the number of pigs born at subsequent farrowing.

Source of Variation	d.f.	ss.	m.s.
Total	17	38.67	
Between mating seasons	2	13.02	6.51 xxx
Between years	5	3.54	0.70
Discrepance	10	22.11	2.21
Within years	122		1.23
Subclasses			
Between years	17	179.5	10.6
Within years	122	964.5	7.91
Total	139	1144	

F. Between mating seasons and within years

= 6.51/1.23

= 5.3xxx d.f. = 2:122

P = less than 1%

F. Between mating seasons and between years

= 6.51/.70

= 9.3xx d.f. = 2:5

P = less than 5%.

It is possible, that since in the analysis of variance the individual litters composing the classes are each treated separately in the course of the technique and thus register an effect on the results obtained, that this technique may be more appropriate than the chi-square treatment. However, since there is a reasonable margin for doubt in the matter, no undue reliance can be placed upon the significance of the above results.

Data regarding time of farrow were arranged in periods similar to those relating to time of mating.

The means for period classes and years within these classes are given in Table XIX.

TABLE XIX.

Mean litter size of sows grouped according to time of farrow.

	Period.		
Year.	1.	2.	3.
1935	9.6	13.0	7.5
36	8.0	8.3	8.3
37	8.6	9.0	7.9
38	8.1	8.6	8.2
39	7.6	8.9	8.7
40	8.5	8.4	8.2
Mean for total litters born	8.4	8.8	8.1

The total number born within classes was reduced according to the number of litters in the smallest class and the totals treated by the X^2 method. There was no significant difference among the classes treated all togather, nor between any combination of two.

An analysis of variance was carried out also, and the results are presented in Table XX.

TABLE XX.

Analysis of variance of effect of season of farrow upon litter size.

Source of Variance	df.	ss.	ms.
Total	17	24.5	
Between seasons	2	5.4	2.7
Between years	5	7.2	1.44
Discrepance	10	11.9	1.19
Within years	113		1.48
Subclasses.			
Between years	17	72	4.23
Within years	113	975	8.62
Total	130	1047	

F. Between seasons within years 2.7/1.48
= 1.82 d.f. 2:113

Non significant.

It may be safely assumed that the season of farrow has little or no measurable effect upon litter size.

Table XXI combines the means for the total numbers born within classes according to time of mating and time of farrow.

TABLE XXI.

Comparison of influence of time of year of mating and of farrowing upon litter size.

	1	2	3
Season of mating	9.1	7.71	8.32
Season of Farrow	8.4	8.8	8.1

As stated previously, the major environmental factors influencing litter size under the above heads, are common to both. The difference lies in the incidence of these factors, in regard to stage of pregnancy, upon the animal. If a conservative view is adopted and the difference between periods 1 and 2, according to season of mating, is the only difference accepted as significantly great, it is of importance to find some explanation why this difference should arise and why the differences between seasons 1 and 3, and 2 and 3 was not significant.

The sows mated in December to March were subject to optimum conditions in regard to feed and temperature and sunlight at the time of and immediately subsequent to mating. This is a reasonable assumption in regard to the College herd and also to the majority of herds in this country. Dry sows are, at this time of the year able to obtain a certain amount of grass, depending upon the nature of the rainfall, etc. and milk or whey supplies are usually sufficient to allow at least two reasonable feeds per day of these easily digestible foods.

Since sows farrowing in this period are also subject to the same conditions, or probably better conditions, and yet produce litters that are not significantly larger than those produced in subsequent periods, it is reasonable to assume that the effect of a high plane of nutrition and high temperatures immediately subsequent to mating is more effective in securing large litters than a similar plane and temperatures just prior to farrowing.

This hypothesis may then be applied to the two remaining seasons, although the differences observed in the litter size are not large enough to be significant.

In the April to July period the weather conditions and food supply are both considerably poorer than in the December to March period. As a result, the sows mated in this period are subject to a comparatively low plane of nutrition and prevailing low temperature and possibly reduced sunlight, and produce fewer pigs than when mated at any other period of the year. On the other hand the tendency seems to be for sows farrowing in this period to produce slightly larger litters than at other periods. This result is what might be expected as, in the majority of cases, sows farrowing in the season April to July are mated either in December to March or at the latest early in April. They have included in their pregnancy period a comparatively advantageous plane of nutrition. This then shows its effect on the number born in the April to July season. At the same time, sows farrowing in the latter part of this period have to subsist to a large extent on roots and a limited amount of meals and dairy by-products, immediately prior to farrowing, but still average litter size tends to be high. This further indicates that the incidence of a high plane of nutrition is more important in relation to litter size, early in the pregnancy of the sow than it is later.

A somewhat reduced effect is seen in season 3, August to November. This period covers the time when dairy by-products supplies are increasing rapidly, when grass is growing and sunlight is increasing in intensity and duration.

It is evident however, that sows mated early in this season may be penalised in regard to available supplies of feed. Sows farrowing at this time are naturally fed their requirements, as are store pigs and early weaners. Later in this period both food and weather conditions improve and then become even more advantageous than in December to March period. Thus the fact that sows mated in this period produce litters that are in size mid-way between those produced in the other two season, may be attributed to the sudden change within this period from disadvantageous to advantageous conditions, while any particular group may be a reflection of either.

Sows farrowing at this time tend to produce very small litters and this may be explained as before by the fact that for the most part such sows were, at the time of mating, subject to poor feed conditions and also to poor conditions in regard to warmth and sunlight, and any effect of rising feed supplies in their season of farrow seems once again to have been unapparent.

Discussion.

Overseas and New Zealand results tend to support the above conclusions.

McKenzie (1928) states that a definite correlation exists between the gains in weight by sows the month following mating and the number of pigs farrowed.

Zeller, and Johnson, and Craft (1937) found that there was a tendency for the number of pigs farrowed to increase with increased rate of gain of sow during gestation.

This conclusion may be exceedingly relevant in that it places the emphasis upon "rate of gain." It is possible that a sow in low condition prior to mating or being placed on a high plane of nutrition, not only gains weight more rapidly but also are more healthy than sows fairly fat prior to mating and maintained on a high nutritional plane. Such a state of rising condition would, under such circumstances, constitute a case analagous to that of ewe flushing at tupping.

Certain qualifications are necessary in connection with this work. It is stated that sows suckling large litters and heavy litters lose weight very rapidly during suckling, and that such sows put on weight rapidly, or make rapid gains subsequent to weaning. They then say that the number of pigs farrowed increases with the increased rate of gain of the sow during gestation. If we are to assume that a sow weaning a big litter loses weight rapidly and a sow low in weight puts on weight rapidly during gestation, and they admit the probability of this, and that a sow making rapid gains in the course of the gestation period produces a large litter, then surely, we can merely say that a sow producing a large litter at one farrowing produces a large litter at the next farrow when fully fed. The results may also be interpreted by saying that high milking capacity as measured by loss in weight of the sow during suckling, and high weaning weight of the litter, is associated with high prolificacy. This is further supported by the statement that parts of large litters were put on to sows with small litters and so loss in weight was not necessarily proportional to the absolute size of litter suckled. There is no indication, however, as to what method was adopted acrediting such fostered pigs or their mothers or foster mothers in regard to loss in weight, weight of litter weaned or in relative mortality from birth to weaning. Further, no account is given of the relative gain in weight of the sows during successive time intervals in the course of gestation. In this respect Ballinger (1940) in a progress report on the influence of nutrition during gestation, upon litter size, concludes that the plane of nutrition immediately subsequent to mating is of greater significance, but gives no account of weight losses of sows weaning large or small litters.

Ballinger's results are also in agreement with those of Morris and Johnson (1932) who state that small litters resulted when sows were on a poor diet.

It would seem, therefore, in view of McKenzie's results (1928) and Ballinger's (1940) and the indications derived from the study of the College herd, that nutrition following mating is of prime importance in relation to the size of litter farrowed. Hammond's conclusions may well be mentioned in this respect, he states that "the production of a large number of eggs per ovary frequently outstrips the nutrition available for them and leads to atrophy either of follicles, newly fertilised ova, or as partially developed embryos." And since he further concludes that the fertility of pigs and rabbits is limited by the number of eggs shed at each period and the number which develop to normal young, or, the number of degenerating foetii, then it is of prime importance that conditions should be such that the sow is enabled to shed a large number of ova at the time of oestrus and support the development of these during gestation, and in this respect it is surely essential that the plane of nutrition should be high at mating and for some time subsequent to this.

Results obtained by other workers tend to support the view that season of farrow has little effect upon the size of litters produced.

Zorn, Krallinger and Schott (1933), Krizenecky (1928) and Ballinger (1940) accept this conclusion while Pearl (1918) and Machens (1918) state that season does have an effedt - but hold opposing views in regard to which season is responsible for higher prolificacy. Pearl records larger litters in the Spring with the exception of the Southern states of U.S.A.

and Machens credits the months, September and March, with higher prolificacy in sows farrowing at this time.

As has been mentioned, the three major environmental factors likely to influence litter size as between seasons are, feed supply, temperature and sunlight. The latter is not yet of proven importance. In New Zealand feed supplies are for the most part subject to extreme fluctuation and control of temperature differences by requisite housing conditions is not of a very high standard. In view of this situation, it is a reasonable assumption that, if season of farrow were to exercise any significant effect, upon litter size this effect would be more readily observed under our conditions than in the case of American, or European standards where food supply at least, is so much less influenced by season. But results of the present work, and Ballinger's results from which he concludes that a high plane or low plane of nitrition just prior to farrowing is less important than similar planes subsequent to mating, indicate that the fact that a sow farrows in any particular season, and in consequence is subject to the general food supply conditions specific within that period, is less important than whether or not mating takes place within this season. These findings relate only to the total number of pigs born per litter and not to the number born alive. Feed conditions or temperature may possibly exert an influence on prenatal mortality at any time during the gestation period, but foetii dying early in pregnancy are usually resorbed within the sow and so are never recorded in the normal course of events.

THE INFLUENCE OF THE BOAR ON THE SIZE OF LITTERS SIRED BY HIM.

In this study the matings of eight boars arranged in various groupings of two, both serving the same sows, were observed. In all, 156 litters were studied, this number including repetitions of the same observation in the course of pairing the boars.

Data of size of litters from the same sows were grouped and treated by the T test and the results are set out in Table XXII. Only averages between which there appeared to be a difference great enough to yield significance were treated.

In arranging the groups of sows, as mated, some litters had to be eliminated in order to reduce classes to the same size. This was done by eliminating those litters from the same sows in the larger class furtherest away chronologically from the actual litter in the smaller class, e.g. Sow 1 has three litters by boar A. and five litters by boar B. The three litters by boar A. are 4th. 5th. and 6th. litters. The five litters by boar B. are 1st. 2nd. 3rd. 7th. and 8th. Then the litters 1st. and 8th. are eliminated. It is felt that such a method would involve less spreading of environmental effects and also reduce any effect of age as applied to an individual sow. The fact that sows farrowed more litters or fewer litters by one boar than by another is not important from the view point of statistical technique, as long as total of litters from all sows by both boars is, in each case, equal.

The arrangement of matings in columns does not mean that the same sow is refered to in the whole column, but merely indicates that, in each case the same sow is mated to the two boars in the group.

Table XXII.

Comparison between size of litters sired by boars in reciprocal crosses.

(Table XXII continued over page)

Table XXII.

Comparison between size of litters sired by boars in reciprocal crosses.

	SOWS.									
BOAR.	1,	2.	3.	4.	5.	6.	7.	8.	$\bar{x}$	t.
2824	6/9	7	6/4	10	11				7.57	
6105	9	7	7	9/10/12	9				9.0	1.2
6105	9	9	9	8	12				9.4	
5830	11	3	14	4	10				8.4	0.45
5830	9	7	6	4	10	9	8/8	14/6	8.1	
9455	11	3	9	8	10/4	7	4/6	11	7.3	.62
9455	5/8	5/8	6	6					6.3	
11314	10/9	7	3	5/6					6.0	
11314	13	9/5	7	7	10	6			8.14	
11206	11	11	5	5/11	11	7			8.7	
5830	11	8/5		6/7	8	14			8.4	
11206	10	11/11		12	11/11	9			10.7	1.86
9455	11	5/8	8/5						7.4	
11206	10/10/9	11	5						9.0	
2824	9/13/7	8	8	10/9/6		14			9.3	
3266	11/11/12	7	8/5	12/8		10			9.3	
2824	9/13/7	8	10/10	12					9.6	
3913	14/14/14/10	8	8	10					11.14	1.22
3266	11/11	8/5	12/8						9.16	
3913	14/14/14/10	8	8						11.33	.71

As shown by Table XXII, though the mean size of litters sired by two different boars from the same sows may differ, in no case is the difference significantly great. It may be concluded from this comparison that the boar has exerted little or no measurable influence upon the size of litters farrowed by sows mated to him. While this is in accordance with other work on the subject, it is suggested that environmental factors, such as season, temperature, food supply etc, may have exerted a profound effect, but it is unlikely that, even with these factors allowed for, any significant difference would be observed. Such factors were impossible to allow for because of the smallness of the numbers concerned,

That the boar does not influence the size of the litter served by him is an opinion held by Bywaters, Culbertson and Hammond (1934), Hetzer (1940), Smith (1931), Ostermayer (1934) and Krallinger and Schott (1933). McPhee quotes a significant correlation between the size of litter in which the boar is farrowed and the size of litter sired by him. He states that this is open to question.

It would appear at first sight, that since the part played by the boar in the production of any litter through sows mated to him, is purely physiological in nature, little or no credit or blame is attachable to him in regard to the size of the litters produced.

If a normal boar and sow are mated at a time during oestrus when ovulation is most active, or just subsequent to t this, then it should rest with the sow as to how many young are produced. However, it may be well to qualify this and say rather, that the absolute number of ova fertilised depends upon the sow at this time, because firstly, the male ejaculate bears spermatoza far in excess of the number of ova shed by the sow, and therefore, this latter factor must be the limiting one in regard to the number of ova fertilised, and secondly, between actual fertilisation and parturition, factors peculiar to the zygote rather than the sow, or the ova shed by her, may very well condition the actual number of pigs born.

Excluding for the moment the question of sterility, absolute or partial, Hammond (1921) working with uteri of breeding sows, concludes that the number of ova shed and fertilised in the sow is not as important in relation to size of litter produced as is the extent of prenatal mortality of the developing foetii. It is admitted that environmental factors materially affect the chances of survival of the unborn young. Probably nutrition exercises a major influence and Warwick (1928) working with similar material suggests crowding and nutritional deficiencies as causes of death in some cases, but he postulates as even more important, genetic factors, and supports this by stating that degeneration of foetii was observable when overcrowding could not possibly have taken place.

This suggestion in regard to genetic factors is lent some point by work done by Williams (1938) who used inbred sows and inbred boars in outcrosses to unrelated stock. Litter size was then restored in both cases and he concludes therefore, that the reduction in the size of litters observed in the inbred strain, when inbred sows were mated to inbred boars, could not have been due to lack of ova developed by the sows or fertilised by the boars, but to reduced viability and consequent degeneration of the zygotes and foetii.

This, of course, is an extreme case and probably the results observed are due to the concentration of factors either inimical todevelopment or causing greater susceptibility to disadvantageous external influences by close inbreeding.

Hetzer (1940) in an inbreeding experiment with the Chester White breed states that mortality varied between litters sired by different boars. This was, of course, a post-natal observation, but it is surely reasonable to suppose that differences in post-natal viability may well be accompanied by similar differences pre-natally. It does seem possible that boars, even as used in the course of operations on an ordinary commercial herd or stud, may differ in their effects upon intra-uterine mortality.

From a purely practical point of view, however, it is doubtful whether such differences are really important, since, judged by the number of pigs born to these sires, no significant difference can be observed among their performances.

Again, if pre-natal mortality is high enough to make itself evident, then the genetic constitution of the sow doubtless contributes in equal amount to the incidence.

On the other hand, if pre-natal death is the limiting factor in litter size it is essential that a thorough study should first be made of the effects of environment upon the extent of this feature with a view to increasing litter size.

In this respect the Danes attribute some proportion of the improvement in prolificacy among their herds to their improved husbandry of recent years, and there is little doubt that a similar effect would result in this country if greater care were taken of the brood sow.

It is possible that a further improvement might be made by the mating of boars to unrelated sows and by slaughter or operation, examining the contents of the uterus and the number of corpora lutea present in the ovary and thus arriving in a series of matings at the effect of the boar upon this highly important factor. As a method of proving boars of a highly prolific strain this may have possibilities though the cost would be too high for it to be practised on any scale and in any case, with improved husbandry, careful mating and nutrition our present stocks are probably capable of producing litters of ten to twelve, and such litters if treated well are held by many to be of an optimum size from the point of view of possible milk supply by the sow, and also in regard to the percentage of mortality from birth to weaning. Even when the effect of environment is allowed for, it is difficult to decide whether the difference observed in the prolificacy of sows is a result of differences in the number of ova shed, or in the indidence of intra-uterine deaths.

If, as seems likely, both are basically genetic, although influenced by environment, then in breeding and selecting for increased litter size both sets of factors are concerned and improvement may be due to either, alone, or both together.

A discussion on the effect of the sire would not be complete without mention of the relative fertility exhibited in boars. Nordby(1928) quotes references to boars that, while apparently normal and active either failed to settle their full quota of sows or sired very small litters in those that did conceive. In view of the results of recent work carried out on semen of dairy bulls and flock rams, it is highly probable that such cases may be more common among pigs than the literature on the subject indicates, and no doubt there are boars, the semen from which contains a very low concentration of viable sperms. There is scope for research on this problem in deciding whether and to what extent, genetic and/or environmental factors are more importan

Funquist (1919) (Smith) reports a strain in which the boars, although producing fertile sperms, were incapable of the performance of mating. He attributes this to a recessive sex-linked type of inheritance.

In respect of relative fertility rather than infertility Webster, of Massey College, in unpublished data, attributes the high lambing percentages of some of the rams used, to the great motility and viability of the sperm produced, and sugges suggests that these rams were more successful in that their sperm remained motile sufficiently long, in the uterus to fertilise ova shed late in the heat period.

This work of Webster's may prove complementry to work done by Haring (1938), and Krallinger and Schott (1933) conclude from their experiment that the time of mating has no effect upon fertility, while Haring (1938) using black boars and white boars with black sows considers that ovulation takes place usually 24-36 hours after the onset of oestrus and service in the first 12 hours resulted in few or no sperm remaining alive long enough to fertilise ova shed then. Mating on the third day was also unsuccessful. The effect upon litter size of using a boar for service too frequently, and not allowing for a rest period, may be mentioned.. Hammond (1940.) suggests that sires should be allowed three days between matings if the best results are to be expected.

Good husbandry then, demands controlled matings about 48 hours after the onset of oestrus, but it is possible that sows fluctuate greatly in the time of ovulation, and also, in some animals signs of oestrus are difficult to see and so the exact stage at which any sow is at any definite time is difficult to establish, hence a great deal will depend upon the boar, as to how many ova will be fertilised.

From a study of the literature therefore, it would appear that while the actual fertilisation rate will depend upon the number of ova shed by the sow, when due attention is paid to the time during oestrus that mating takes place, the number pigs born will depend upon (1) nutritional and general environmental conditions to which the sow is subjected during gestation, with the aim of reducing pre-natal mortality as far as possible, and (2) the possibility of the viability of the foetii being influenced by the genetic constitution of the boar as well as the sow, which may become evident in extreme cases such as when close inbreeding is practised.

Under general New Zealand conditions of pig husbandry the former is without doubt the major factor, and until improvement in sow nutrition, housing, and treatment is achieved the genetic nature of any influence the boar may exert is of decidely minor importance in achieving a consistently high standard in litter production.

THE INFLUENCE OF THE DAM AND SIRE UPON THE SIZE OF LITTERS PRODUCED BY THEIR DAUGHTERS.

Introductory.

For some years the mode of inheritance of prolificacy has exercised the minds of research workers; the results have been published of work carried out in Great Britain, United States, Germany, Denmark, Sweden and Russia, but as yet there is very little of a constuctive nature to report. Various methods of selection, that have been used by farmers in their endeavours to breed for greater prolificacy, have been proved to be unsound, and, so far, it is in this respect of the problem that research has proved of greatest value.

In summarising the available literature on the inheritance of prolificacy the data are treated under the following heads:

(1) Methods of selection and their efficacy.

(2) The results of inbreeding.

(1) Methods of Selection and Their Efficacy.

In Kansas Experimental Station Report (1916) it is stated that selection of dams and sires on the basis of the size of litter in which they were farrowed, has no influence upon the litter size of the progeny, and this view is supported by McPhee (1931), Johnson and Morrison (1932) and Henke (1935). It may be mentioned that the practice still persists of selecting breeding stock from large litters and Buchanan Smith (1930) in reporting upon Simpson's work (1912) where a Tamworth sow was crossed with a wild boar from Germany sees fit to add that the sow in question was one of a litter of twelve, giving to understand that this fact is a sufficient criterion of her prolificacy.

Keith (1930) suggests that the size of litter produced by a sow is a valuable criterion in selection for fertility, while Hammond (1926) prefacing his remarks with the statement that "prolificacy is inherited" states that litter size can be improved by selection even though the distinction between high and low producers may be obscured by poor husbandry conditions. Smith (1930) supports this view and says that unless breeders constantly select for prolificacy it is likely that the fertility of their herds will decrease. At the same time he points out that in the improved breeds, hereditary factors are perhaps not as important in regard to litter size as good husbandry and the mothering ability of the sow.

Johansson (1929) reports that though selection for prolificacy had been practised in a particular herd for twenty five years, no increase in litter size resulted. Smith (1930) claims that this merely means that Johansson had achieved a strain that more or less breed true for litter size.

Stutt (1940) in reporting upon the results of pig-testing in Pomerania claims that the Edelschwein breed from 1929 to 1936 had shown an increase in average litter size from 9·8 to 10.1 pigs per litter and the improved Landschwein from 10.3 to 10.6. In Denmark similar improvements have been made but it seems very likely that some of this improvement may be due not merely to selection but also to improved husbandry as a result of quickened interest and incentive in pig keeping, which naturally follows the institution of shows, pig clubs and recording schemes. The Danes, too, record a reduction in the food units required for the live weight gain of one pound, from 3.79 to 3.39 units and a decrease in the time taken to reach killing weight, of 8.5 percent. The fact, therefore, that prolificacy has been increased may be, in some part, due to the increased nutritive efficiency as well as better husbandry, directly influencing the pre-natal mortality which is one of the major limiting factors in the number of pigs born in any farrow. Hammond (1921).

Eckoff (1936) reports that in Germany during the period 1924 to 1936 the fertility of pigs has been increased from 14.7 to 17.8 pigs per sow per annum, but it is quite probable that much of this increase has been due to stimulated interest and education in husbandry methods as a result of the institution of the recording system in 1924.

While mention has here been made constantly to environmental conditiens in relation to recorded production increases, no doubt selection for the inherited quality has played a part in the improvements. However, these advances have been small and since environment has probably played a helpful role, it is obvious that that part of the advance attributable to selection must be only a proportion of the whole, small though that whole may be.

What then is a sound method of selection? If the size of litter in which the sow is born is not a valuable basis for selection then it may be that the boar is at fault. At the present time and in the past, various methods of using good boars as premium sires have been practised. In Sweden since 1928, boars can only be registered in the State Herd Book if they are out of sows that have been officially tested and have passed a fixed standard. In Germany, the use of boars is controlled by a commission. Selection of sows is based upon performance records in Germany, Denmark and Sweden. In England the premium boar scheme is in operation, but selection is based upon phenotype and possible genotype. Such schemes appear to have resulted in an improvement in stock quality but there is no apparent record of any effect that these sires may have exerted upon prolificacy.

Thus, while there is a general acceptance of the fact that litter size is inherited, selection on the female side has not proved wholly effective when used as a general plan. No really significant correlation can be cited as between dams and daughters, and very little attention seems to have been payed to the selection of sires on their performance.

It is realised that selection can seldom have been practised entirely upon prolificacy, such factors as carcase quality, conformation, relative growth rates, etc. Have "diluted" the selective force and therefore, spectacular results can hardly be expected.

Within the last ten years statistical treatments have been applied to various data and some measure of the importance of genetic factors in litter production has been determined. Lush, Anderson, Culbertson and Hammond (1933) estimate that 13 to 14 percent of the variance in litter size is due to sow individuality. They also state that where close attention is payed to selection on the basis of prolificacy as judged by the size of litters, it would take ten to twenty years to increase the average by one pig. These results agree fairly well with those of Hetzer et alia (1940) who estimate that 20 percent of the variance in litter size is due to sow individuality, but because of the incidence of such factors as health etc. they consider that somewhat less than this 20 percent is due to heredity.

If such is the case, the lack of significant correlation between the production of successive generations of animals is readily explained, especially as the boar must also have an influence on the prolificacy of the female progeny of the dams to which he is mated. Beyond the admission that the sire is probably responsible for half the genetic influence upon litter size, (Smith (1930)), it does not seem to have been possible to make any precise study of the absolute influence of the sire in this respect.

An interesting method of progeny testing boars is described by Kudrjavcev, Damova and Grudev (1937) in which the assumption is made that the performance of the daughters is derived equally from the dam and the sire. This is merely used as a working hypothesis and no attempt is made to justify the assumption.

A further consideration is involved in this connection, and that is, what is the measure of performance which can be accepted for judging whether or not an animal is prolific? Kudrjavcev and his co-workers defend the method of accepting the first litter of a sow as sufficient indication of her fertility, claiming as their justification that there is a high correlation between the first litter and subsequent life performance. That there is such a correlation is supported by Keith (1930) and McPhee (1931). If this method of assessment of breeding value is sound then the proving of boars and sows becomes a much simpler business and selection on individual performance could be adopted rather than the performance of ancestors. This method may be satisfactory with large scale farming but it is scarcely so applicable to the small private farm where the individual pig assumes a much greater importance,

(2) The Results of Inbreeding.

The results of inbreeding upon prolificacy present very definite evidence in support of the genetic nature of this feature. As a method of breeding Hays (1930), McPhee (1930), Craft (1931), McPhee, Russel and Zellar (1931) and Hetzer <u>et alia</u> (1940) found that inbreeding resulted in a reduction in litter size at birth. In opposition to this view are the results of Hughs (1933) Jacobiec and Marchlewski (1933), Hodgson and Clarke (1934), Ritzoffy (1933) Bywaters, Culbertson and Hammond (1934) and Hodgsen (1935) who all failed to find a decrease in litter size with inbreeding, but in no case was litter size increased materially though, in all, selection was practised with this end in view. Eckstaedt (1929) states that the eff ect of inbreeding upon fertility is variable, in some cases improvement resulting and in others litter size being lowered.

The statements of Wentworth and Aubel (1916), Crew (1924) and Smith (1930) in regard to the mode of litter size inheritance are interesting in the light of the results obtained in the carrying out of inbreeding work.

The writers all agree that large litter size is inherited as a recessive character. They do not hazard any guess as to how many factors are involved, but Smith (1930) does remark that the inheritance of litter size is not very complicated. If large litters are dependent upon recessive factors, then, in the course of inbreeding one would expect at least a few outstanding individuals. This is not unreasonable since other characters similarly dependent upon recessives such as cleft palate or atresia ani are usually unearthed as a result of this method of breeding. However, there is at least one possible explanation for this failure of segregation of the factors concerned with large litters, and this is found ~~to be~~ in Willham's work (1938). Willham, as results of matings of inbred sows to unrelated boars and inbred boars to unrelated sows, considered that the small litters produced by inbred matings were not due to lack of ova shed by the sow, or lack of fertility on the part of the boar, but suggested a concentration of factors which increased the pre-natal mortality of the fertilised ova and foeti. Hammond's work (1921) on the incidence of mortality in utera lends further point to this work, as does that of Warwick (1928) and to a lesser extent a similar project by Crew (1926). Hammond's results (1932) on foetal mortality in two inbred strains of rabbits may be cited as additional evidence of the importance of this factor in the number of young born in any birth. All the above workers stress the importance of pre-natal mortality in relation to the number of pigs born in a litter and it may be that in the cases reported where litter size is reduced by inbreeding, there is a concentration of the recessive factors postulated by Crew and Smith as being responsible for large litter size, but the concentration of recessive lethals is even more important and judging by the actual number of pigs born to the stock, prolificacy has been reduced or at the best kept normal.

The truth of the above suggested explanation could be tested by the slaughter and examination of the uterine contents of sows inbred for several generations, and if no similar explanation applies, then it becomes rather difficult to see the justification for the suggestion that large litter size is dependent upon recessive factors.

In the light of the above work, it is evident that in any study of prolificacy we are concerned with at least three major sets of factors, namely those affecting the number of ova shed, the number surviving of those fertilised, the latter feature probably depending upon both hereditary and environment.

It seems likely that the improvement in prolificacy obtained in several European countries is largely the result of improved husbandry where farming tends to be intensive and labour more plentiful than in New Zealand. At the same time appreciation of the part played by the sire in the inheritance of litter size has not been given due consideration, and selection on the female side on performance and the male side by progeny testing should be fully exploited together with a higher standard of feeding, housing and handling of breeding sows, if consistent and appreciable improvement is to be achieved.

Results from the College herd.

A study of the records of the College herd was made. Unfortunately in such a small herd, it can hardly be claimed that any strain or strains have been developed and boars "bought in" as well as others bred in the herd have been used widely. The result is that whereas the female lines may be arranged according to three foundation sows, the rather promiscuous use of boars has destroyed their identity as distinct families. Then, too, the use of 19 boars on 57 sows in 13 years has not allowed for any great number of daughters from any one boar to be kept although, of course, no daughters were retained for breeding in the case of some sires and several from others. Consequently any analysis on statistical lines becomes impossible.

It is interesting to observe just to what extent selection for litter size has had an effect upon increasing

Table XXIII

Comparison of size of litters of sows culled in respective years as a result of death (1), age*(2), low production (3) with size of litters of sows retained in the herd (4).

	1933/4				1934/5				1935/6				1936/7				1937/8			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
No. sows.	-	1	1	4	-	-	4	6	1	-	5	8	2	-	8	11	1	1	2	10
No. litters.	-	1	1	7	-	-	6	10	1	-	5	13	2	-	13	19	1	1	3	19
No. pigs born	-	7	3	62	-	-	41	104	11	-	33	113	15	-	113	158	3	3	23	162
Mean litter size.	-	7	3	8.8	-	-	6.8	10.4	11	-	6.6	8.7	7.5	-	8.7	8.3	3	3	7.6	8.5

1938/9				1939/40			
1	2	3	4	1	2	3	4
1	3	4	10	1	-	5	9
1	4	5	14	2	-	88	120
9.0	7.0	8.6	8.0	12.0	-	9.7	8.0

Age* Here a sow is regarded as aged after producing 8 litters.

the prolificacy in the course of the herd's development. This is shown in Table XXIII.

Table XXIII is not expected to represent a comprehensive picture of a basis of selection. It is realised that in any practical selection the supplementary factors of number born alive, weaned, and weaning weights in any litter are equally important with litter size in deciding whether or not a sow will be retained in the herd. For this considerat--ion, however, it is not important to know why the sows in the respective years were culled. It is sufficient for the present purposes that the broad relation of litter size to culling practice should be shown. If in any year, the mean litter size of sows culled does exceed that of sows retained, as actually happens in the years 1936/7, 1938/9 and 1939/40 then it may be assumed that in these years selection on the basis of other important features such as mentioned above, did not coincide with selection for number of pigs born per litter in the case of the sows concerned.

It may be argued that the use of size of litter farrowed by sows, only within the years considered is not a true measure of their productive capacity. This may well be true, but on the other hand, if any given sow should farrow three good litters and then farrow two very poor litters it is natural that selection will be influenced by the more recent performances rather than life-time record.

As shown in Table XXIII, in four out of the seven seasons considered the retained sows show a higher mean litter size than that of the culled sows. In two of the three remaining cases the position is reversed but the difference is not great. Further in the 1936/7 season there were thirty four litters farrowed while in the 1937/8 season only twenty four were farrowed. Culling was, therefore, fairly severe and as is quite natural a large proportion of the retained sows were first litter sows. In fact eight of the possible eleven fell within this class and these eight young sows averaged only 7.1 pigs per litter. This may well account for the slight discrepancy in litter size between the two classes in the season 1936/7. The difference in the case of the 1938/9 season is again small and the same contributing factor is in evidence in that eight of the fourteen litters farrowed in this season by the sows retained until the following season were first litters.

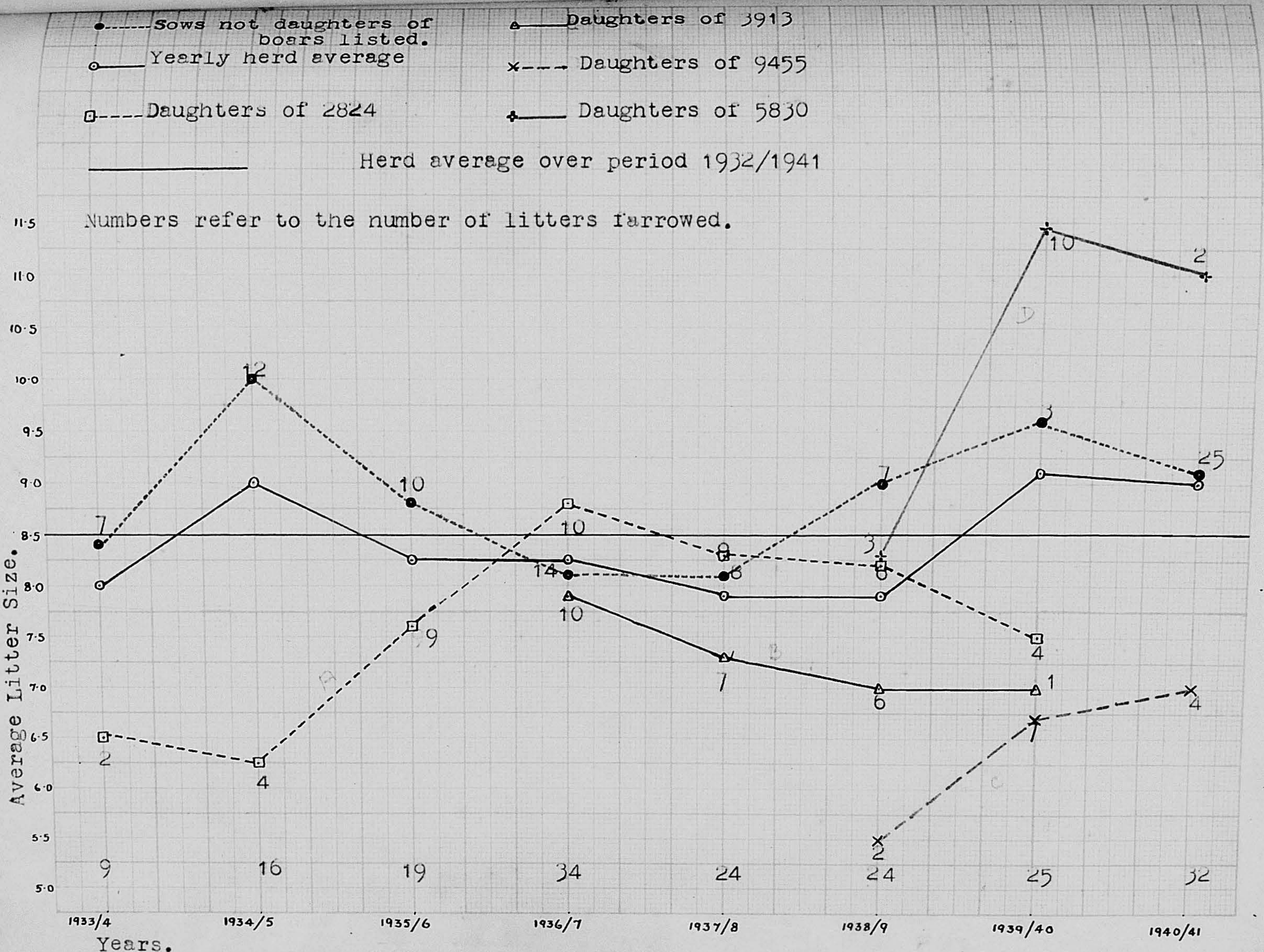
It is safe to conclude therefore, that selection on litter size has been used in the College herd to the extent possible in most commercial herds, where due consideration must also be given to other important economic factors of production.

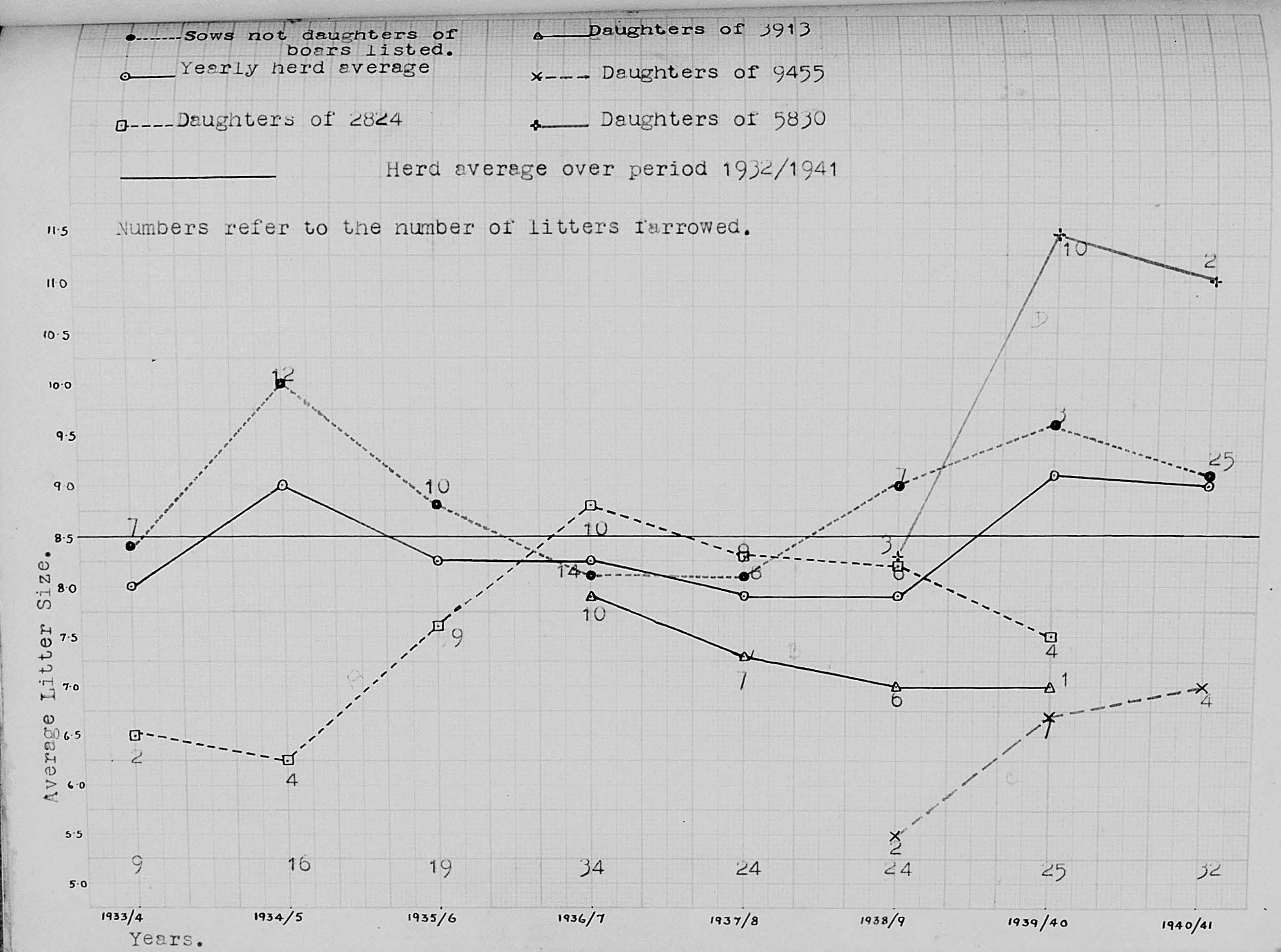
In selecting animals on their actual production, in this instance upon the number of pigs born per litter, it is realised that the selection is phenotypic. As in the case of dairy stock selection based upon butterfat and milk production records, environmental factors play an important part in determining the level of production achieved. The nature of these factors and their importance have already been outlined and discussed.

Inasmuch as number born in a litter from which a breeding sow is selected is not significantly correlated with the production of that sow, and too, since actual production may not be a true expression of genotype, then selection for greater prolificacy becomes exceedingly difficult. If selection could be confined merely to one feature, the position might be eased to some extent, but even then if, as stated by Lush et alia (1933) and Hetzer et alia (1940), only 14 to 20 percent of the variance in litter size is inherited, progress will not be spectacular unless increases follow a curve of geometric progression rather than arithmetic, as homozygosity increases.

As will be seen from Figure III, though selection in the College herd has been to an appreciable extent aimed at increasing average production, the results are very variable ranging from 7.8 to 9.0 pigs born per litter in the period 1933/4 to 1940/1. Even accepting the reservations outlined above, this result is disappointing, and in order to explore the position further the production of the daughters of four boars which have been fairly extensively used in the herd was plotted in relation to sows not daughters of these boars. These results are shown in Figure III.

This Figure is intended to indicate a trend, and not an absolute condition. The sires treated may or may not have had as extreme an effect upon the general average as shown here since various qualifying factors may have been involved. Sows which were mated to the respective boars

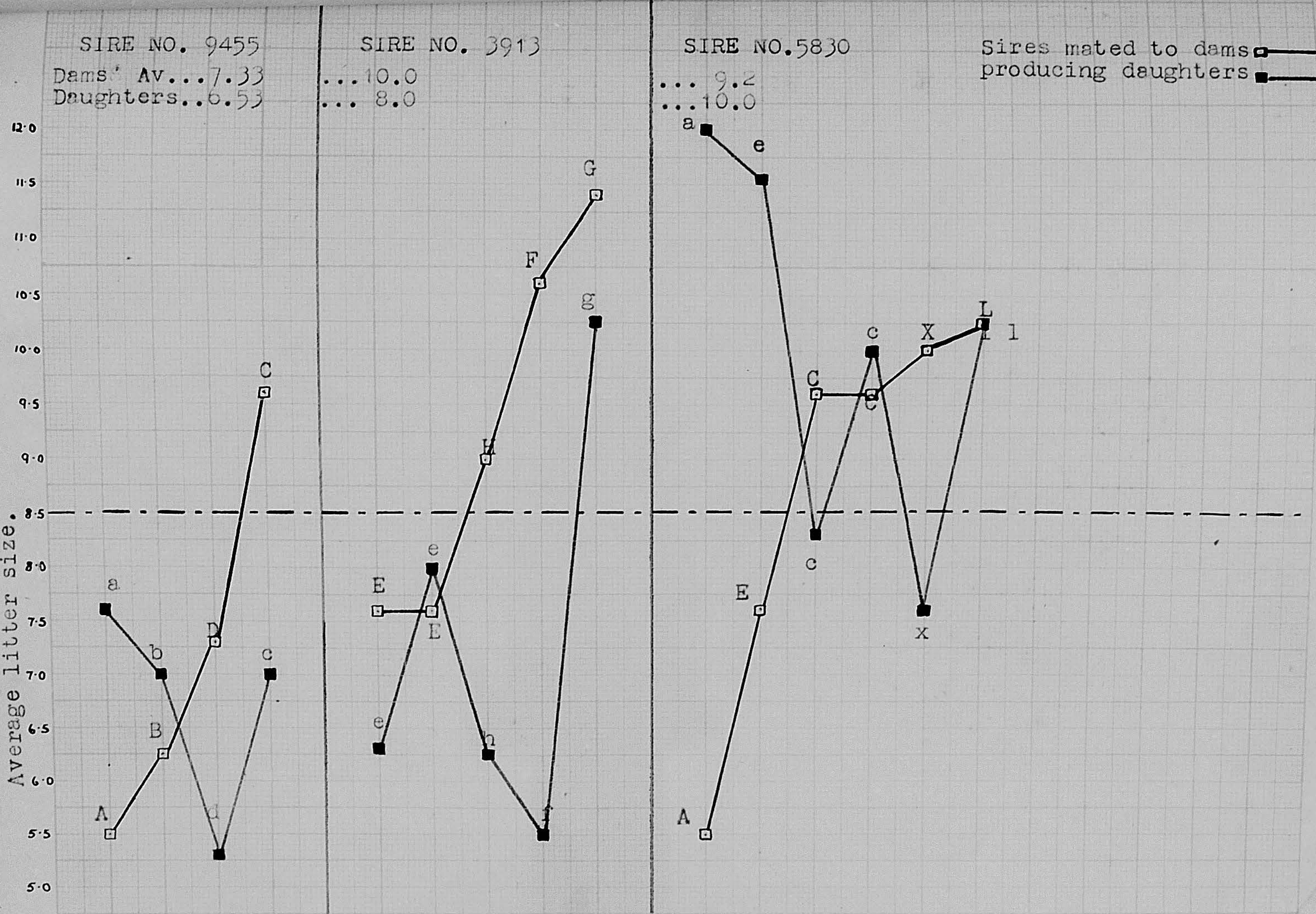

Sows not daughters of boars listed.
Yearly herd average
Daughters of 2824
Daughters of 3913
Daughters of 9455
Daughters of 5830
Herd average over period 1932/1941
Numbers refer to the number of litters farrowed.
Average Litter Size.
11·5
11·0
10·5
10·0
9·5
9·0
8·5
8·0
7·5
7·0
6·5
6·0
5·5
5·0
9
16
19
34
24
24
25
32
1933/4
1934/5
1935/6
1936/7
1937/8
1938/9
1939/40
1940/41
Years.



Sows not daughters of boars listed.
Yearly herd average
Daughters of 2824
Daughters of 3913
Daughters of 9455
Daughters of 5830
Herd average over period 1932/1941
Numbers refer to the number of litters farrowed.
Average Litter Size.
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
9
16
19
34
24
24
25
32
1933/4
1934/5
1935/6
1936/7
1937/8
1938/9
1939/40
1940/41
Years.

farrowed six litters while in the herd, the fourth, fifth and sixth litters of sow A were not considered. While this allows for chronological comparison, it does not allow for seasonal comparison either among daughters or between daughters and dams. Further, no attempt has been made to allow for such factors as season of mating. As a result the interpretation of Figures IV and V shares with Figure III the reservation that a trend only is indicated and not any absolute condition.

The question of numbers too, is one of importance for it is only by treatment of an appreciable number of cases that the many particular and random environmental influences can be satisfactorily allowed for, but as is natural in a herd of small size no large number of daughters of any one sire are available. This position was overcome to some extent in the case of sire 2824 in that some of his daughters have figured consistantly in the herd books and seven of the fifteen daughters compared with their respective dams in Figure V were never producers in the College herd. This naturally introduces a further environmental variable, but on examination it was found that only in the case of one sow was the production appreciably greater than that of her sisters in the College herd and in no case was it appreciably lower. From the point of view of accuracy there may be some doubt about the reliance that may be placed upon the size of litters recorded in the herd books. Certainly the impression gained when examining the production returns as set down in such books is that many


SIRE NO. 9455
Dams' Av...7.33
Daughters..6.53
SIRE NO. 3913
...10.0
... 8.0
SIRE NO.5830
... 9.2
...10.0
Sires mated to dams
producing daughters
Average litter size.
12·0
11·5
11·0
10·5
10·0
9·5
9·0
8·5
8·0
7·5
7·0
6·5
6·0
5·5
5·0
a
b
c
d
A
B
C
D
e
h
f
g
E
F
G
H
e
c
x
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A
E
C
X
L

Figure IV

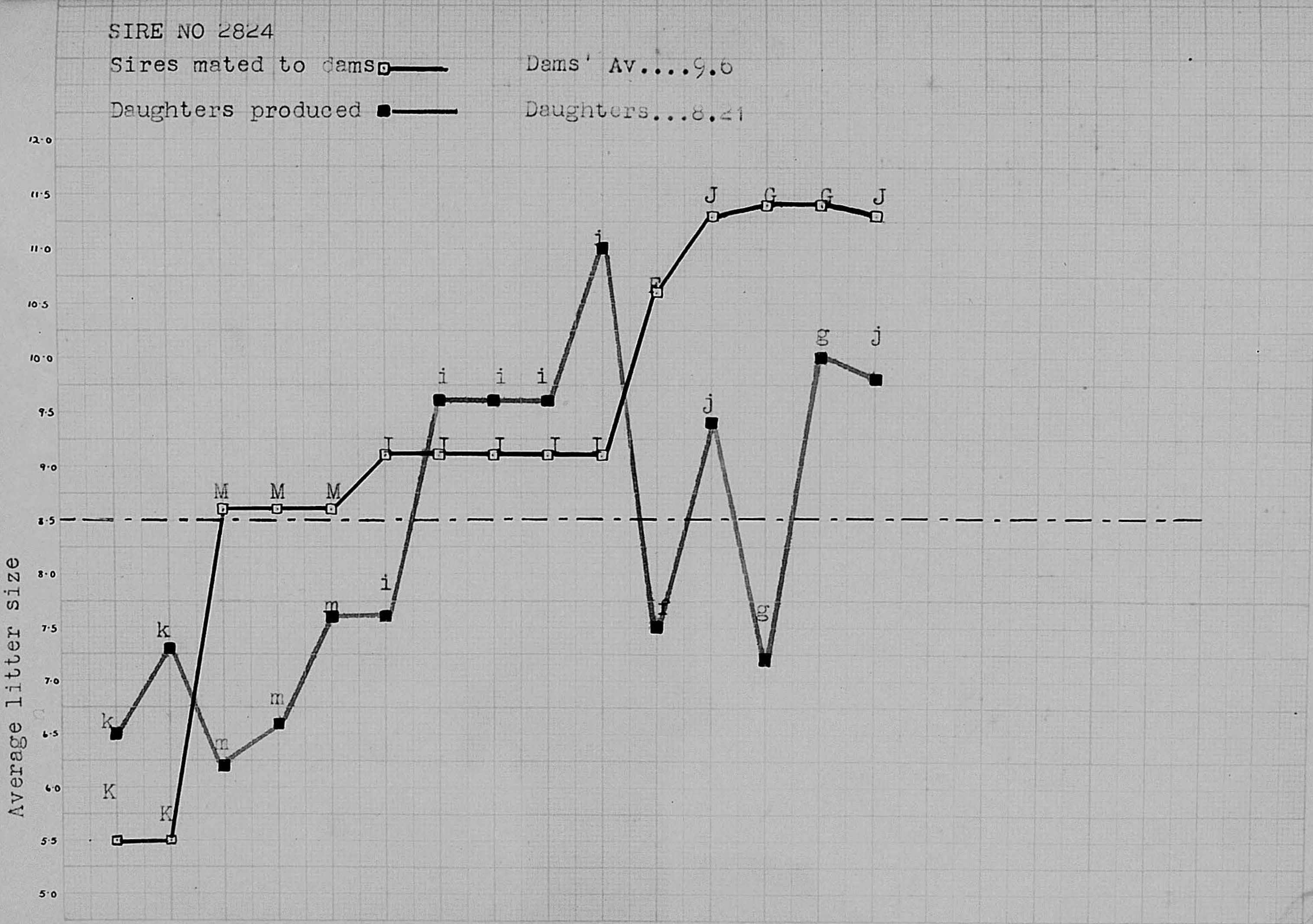
SIRE NO 2824
Sires mated to dams
Dams' Av....9.6
Daughters produced
Daughters...8.21
Average litter size
12·0
11·5
11·0
10·5
10·0
9·5
9·0
8·5
8·0
7·5
7·0
6·5
6·0
5·5
5·0
K
K
M
M
M
I
I
I
I
I
F
J
G
G
J
k
k
m
m
m
i
i
i
i
i
f
j
g
g
j

Figure V

of the breeders only register large litters or that they are inclined to adopt a subtle form of advertising their stock, but such a possibility does not seem to apply in these cases.

If the above objections are sustained, then the inclusion of sows not in the College herd must introduce two serious sources of inaccuracy and for this reason the advantage of additional numbers may be largely offset. However, the position as presented in Figures IV and V bears out the tentative conclusions arrived at from study of Figure III; boars 3913 and 9455 have sired daughters whose average litter size is definitely lower than that of their respective dams. Boar 2824 also shows to a disadvantage and sired daughters whose average litter size was appreciably lower than that of the sows to which he was mated. On the other hand daughters of 5830 show an increase over their dams in litter production.

It may be suggested that the sows mated to boar 9455, having the low average of 7.33 pigs per litter, put this sire at a disadvantage in respect to the absolute litter size of his daughters. From the genetic point of view this is probably not the case in that if the dams produce small litters as a result of relative heterozygosity in regard to favourable and unfavourable genes, then any boar relatively homozygous for the genes favouring high prolificacy would show to advantage when mated to such dams. The possibility that the gene complex of 9455 was similar to that of the sows to which he was mated and that as a result he did not "nick" with these mates, is rather unlikely to hold over four different sows.

It is of interest from the point of view of show ring standards that boar 2824 was an exceptionally good pig, and also, litters sired by him attained a high average weaning weight. Boar 5830, on the other hand, judged by the same standard of show points was quite inferior, and this may well serve as an indication of the necessity of proving boars before accepting them as "premiums" sires, if such a scheme is instituted in this country. It is possible, of course, that the progeny of 2824 may have proven superior to that of 5830 when thrift, and carcase quality at killing weight were considered.

Summarising the information gained from this study of the College herd it may be said that:-

(a) selection of breeding sows on their production in regard to litter size has been practised, if not intensively then at least an appreciable extent.

(b) Average herd production has not materially increased over the period 1933 to 1941 as a result of this selection.

(c) It is not known upon what basis sires purchased or bred for use in the herd were selected, but at least it is known that the basis was not the prolificacy of their daughters.

(d) It would appear that of the four boars treated, three have had a lowering effect upon the herd average and upon the production of their daughters in relation to their dams.

(e) One boar of those considered did produce an improvement, not only in the prolificacy of his daughters over their dams, but also in the herd average in the season 1939/40 when litters farrowed by his daughters constituted 40 percent of the total farrowings for that seson.

(f) Since selection of dams must take account of several factors, and since, therefore, selection on the basis of litter size is curtailed to a greater or lesser degree, it is important that sires should be tested before being used widely, as a means of more surely increasing the effect of that part of female selection which is concerned with prolificacy, in that, of the sows kept fewer are likely to fall below the standard set by their dams or by the ideal of the producer. These conclusions are, of course, subject to greatest attention being paid to environment which is so important in determining litter size by allowing or inhibiting expression of inherited productive ability.

S E C T I O N   I I I.

THE INFLUENCE OF AGE OF THE SOW UPON THE NUMBER OF PIGS BORN DEAD.

This study was made with 196 litters containing in all 1629 piglets. The management of sows about to farrow and farrowing in the College herd involves the presence of an attendant at all times during the process. However, it is practically impossible to fulfil this condition and often sows farrow pigs, or even whole litters in the absence of the pig-man, and for this reason pigs found dead in the pen under such circumstances may be recorded as being born dead when, in fact, attention immediately after birth may well have saved them. With older sows which often become careless and clumsy, especially during farrowing, this may be a contributing factor to the high mortality recorded as prenatal.

The data relating to the College herd are presented in Table XXIV

TABLE XXIV.

Data showing the number of pigs born dead per litter and the percentage of dead pigs of all pigs born, in successive litters 1 to 8.

Litter Number.

	1	2	3	4	5	6	7	8	
No of litters	64	43	29	20	15	11	8	6	
No of pigs born	488	334	268	182	141	92	69	55	1629
No dead	42	41	35	19	31	22	19	16	225
No dead per litter	.65	.95	1.2	.95	2.0	2.0	2.4	2.6	
% dead	8.6	12.2	13.0	10.5	22.0	23.9	27.5	29.0	

It was felt that, as all litters were included in the above table and since many sows are represented but once, the trend may have been exagerated, and for this reason Table XXV was prepared. This table relates only to the litters of sows which have farrowed at least five litters while in the herd.

Table XXV.

Data showing the number of pigs born, the total number born dead, the number born dead per litter and the percentage of dead pigs, based on the total number of pigs born, in sows farrowing at least five litters.

	Litter Number.							
	1	2	3	4	5	6	7	8
No of litters.	15	15	15	15	15	11	8	6
Total No pigs born.	122	119	151	138	141	92	69	55
No of pigs born dead.	11	13	11	12	31	22	19	16
Average No born dead per litter.	.73	.86	.73	.80	2.0	2.0	2.4	2.6
% born dead.	9.0	10.9	7.2	8.7	22.0	23.9	27.5	29.0

There is a slight difference in the values from Table in the case of the second, third, and fourth litters, but the essential feature of the rise from the foutth to the fifth litters is preserved. It is evident therefore, that with increasing age the number and percentage of stillborn pigs and "dead at birth" pigs shows a marked increase, an increase which, from this data, is very pronounced between the fourth and the succeeding litters.

Discussion.

These results are in keeping with the results of other workers. Sinclair and Syratuck (1928) report that the age of the sow seems to be a factor in the production of stillborn pigs, advancing age being associated with an increase in the percentage of pigs born dead. This opinion is shared by Menzies Kitchin (1937), Krizenecky (1937), and Carmichael and Rice (1920). In no case are any suggestions advanced to explain this increase in still-born pigs and no ready explanation presents itself.

The Influence of the Size of Litter Farrowed Upon the Mortality Rate.

On account of the very few sows farrowing less than four pigs per litter it was decided to eliminate these from the study, leaving 179 litters containing 1533 pigs born of which 205 were born dead. Table XXVI records the results obtained from the arrangement of the data.

TABLE XXVI

Showing the influence of number born per litter upon the percentage of still-births.

No. born per litter.	No. Litters.	No. pigs.	No. pigs dead.	% dead.
4	7	28	1	3.57
5	10	50	4	8.0
6	19	114	16	14.0
7	25	175	23	13.1
8	24	192	24	12.5
9	31	279	29	10.4
10	23	230	32	13.8
11	21	231	35	15.1
12	13	156	28	18.0
13	6	78	13	16.6

To test the significance of the observed increase in percentage of still-births with increasing litter size, regression and correlation coefficients were calculated as below.

X	Y
4	3.6
5	8.0
6	14.0
7	13.1
8	12.5
9	10.4
10	13.8
11	15.1
12	18.0
13	16.6
85	125.1

SX = 85 SY = 125.1

$\bar{x}$ = 8.5 $\bar{y}$ = 12.5

SX^2 = 805 SY^2 = 1727.0

$(SX)^2/n = 722.5$ $\qquad$ $(SY)^2/n = 1562.5$

$sx^2 = 82.5$ $\qquad$ $sy^2 = 164.5$

$SXY = 1159.6$

$(SX)(SY)/n = 1062.5$

$sxy = 97.1$

$$Sxy/sx^2 = 97.1/82.5$$

$$= 1.2 \qquad \text{regression coefficient.}$$

$$r = Sxy/\sqrt{(Sx^2)(Sy^2)}$$

$$= 97.1/\sqrt{(82.5)(164.5)}$$

$$= 97.1/\sqrt{13,751.25}$$

$$= 97.1/116.4$$

$$= .8342$$

d.f. = 8

Highly significant at the 1% point.

Discussion.

The increase in percentage of stillborn pigs with increasing litter size is especially interesting when considered in association with the results of studies on the influence of litter size on birth weight. Schmidt, Lauprecht and Vogel (1926), Johanssons (1931), Murray (1934) and Axelson (1928) agree that there is a direct inverse relationship between litter size and individual birth weight. This would indicate that all the members of the litter are affected by the reduced individual food supply, if we regard nutrition as the limiting factor to birth weight.

McPhee and Zeller (1934) report that the average weight of pigs born dead was greater than that of pigs born alive, but Carmichael and Rice (1920) favour the opposite conclusion, and Haines (1931) working with guinea pigs found that the birth weight of stillborn animals was below that of animals born alive. However, while Carmichael and Rice included immature pigs in their average, McPhee and Zeller do not specifically mention that they followed the same system, the difference vetween their results, therefore, may not be real.

If, as stated above, the individuals of large litters are penalised in utero by each receiving a smaller share of the available foetal food supply than would be the case if the numbers competing were fewer, then it is reasonable to assume that, as growth proceeds, those foeti which, by virtue of their position in the uterus or in relation to their litter mates, or, on the other hand, because of their genetic constitution, to mention two possibilities, are unfavourably placed in regard to the increased competition for the available food supply, will succumb.

The possibility that the stillborn pigs may be larger than those born alive may actually be cause and effect, because with the limited food supply the greater size of these pigs may, in fact, prove a disability in that their requirements are larger in proportion. Alternately, they may succumb on account of difficult parturition. Unfortunately there is no way of deciding this point and so any discussion must be conjectural.

The results of other workers support the conclusion that with increasing litter size the percentage of stillbirths increases. Carmichael and Rice (1920) report that litters below the average in size contain 7.7 per cent of dead pigs and those above, 10.5 per cent. The results for litters of the College herd for comparison are, 12.1 and 14.1 per cent respectively. McPhee and Zeller (1934) give 11.7 per cent as the value for still-births in litters of 1,2, and 12 and over, while other litters averaged 3.9 per cent. These last results are in close agreement with those of Podhradsky (1937) who gives 25 per cent for litters of 17; 10 percent for litters of 2 and the lowest value of 4 per cent for litters of 6. The results obtained by McPhee and Zeller and Podhradsky cannot be claimed to be in complete agreement with those obtained in the College herd. Their inclusion of litters containing but one and two pigs would seem to be open to criticism in that, such litters are exceptional and the conditions associated with them may reasonably be considered as differing from those pertaining to litters of larger size. Haines (1931) suggests that the higher percentages of still-births observed in these litters is due to the difficult parturition resulting from the large size of such pigs.

Thus, while there is agreement that with increasing litter size the percentage of still-births rises, with the qualifications observed by McPhee and Zeller, and Podheradsky, in respect to litters of one and two, the close association between the two features as shown in this study seems to be rather exceptional. However, it is safe to conclude that in general, increasing litter size is associated with a rising percentage of still-births per litter.

THE INFLUENCE OF SEASON OF FARROW

UPON PERCENTAGE OF STILLBORN PIGS.

The data for this study were arranged in classes according to three seasons: December to March inclusive (1), April to July (2), and August to November (3). Litters farrowed in the years 1934/5 to 1939/40 were treated. Previously, by an analysis of variance, it was established that no significant difference in size existed among litters farrowed in the three seasons, and so, the influence of litter size upon percentage of still-births can be safely ignored in this study. The data were treated by the chi-square technique as below:-

Seasons	No. pigs born.	No. pigs Dead.	%	Products.
		X	p	pX
1.	437	89	20.3	1806.7
2.	343	87	25.3	2231.1
3.	324	40	12.3	492.0
	1104	216		4529.8

$$SX = 216$$

$$x^2 = \frac{100(SpX - \bar{p}SX)}{\bar{p}\ (100 - \bar{p})} = \frac{100(4529.8 - 4226)}{19.5\ (100 - 19.5)}$$

$$= 19.3^{xxx} \text{ highly significant.}$$

$$d.f. = 2$$

It may be concluded, therefore, that the August to November period is most advantageous in regard to the percentage of stillborn pigs, while April to July is worst.

Discussion.

There appears to have been little attempt to study

Page 83 was not captured

the environmental factors effecting mortality at birth in pigs. McMeekan (1937) reports the following percentages according to the season of farrow.

McMeekan.	% Still-born.	Present work.	
June - August	9.0	April - July	25.3
September - November	5.0	August -November	12.3
December - February	6.7	December - March	20.3
March - May	12.5		

Since the periods do not completely coincide a true comparison is difficult, but although the values for the College herd are higher than those recorded by McKeekan, the trend appears to be very similar.

Morris and Johnson (1932) presenting results from experiments with rats prove quite conclusively that poor nutrition will cause a drastic reduction in litter size, but no mention is made of still-births in this connection., Haines (1931) working with guinea pigs states that the 26th day of gestation period was the significant time upon which the percentage of young born alive depended. The length of the gestation period in the guinea pig being 68 days, the 26th day approximates to the 43rd day of the gestation period of the pig. Naturally, as Haines points out, the influence of any adverse condition is effective over a period of time and not simply restricted to this particular day. It was felt that these results of Haines might well be applied to the data available for mortality in pigs, but various practical difficulties make this impossible. The longer gestation period of the pig which means a longer period over which adverse or favourable influences may operate, lack of detailed records of health and food consumption of the sow over the major part of pregnancy, and the fact that no real control could be exercised over the temperature variations constitute the more important of these difficulties. Also, wide seasonal evidence is hardly sufficient, as conditions in the late summer may be exceedingly dry and grass supply, which forms an essential part of the gestating sows's ration at this time, may become fibrous and dry and provide very little useful nutriment, while in some years good grass is plentiful. This type of discrepancy from year to year is found in any or all of the seasons. Then again it is highly probable that conditions at actual farrowing account for some of the difference in mortality between seasons. In the summer flies and heat will cause sows to be restless and prolong farrowing unduly. In winter months very cold conditions may induce a similar effect, and again, the human element may enter in, for on cold frosty nights the farrowing pen offers little comfort to any attendant. On the other hand - spring and early summer are comparatively cool and general conditions are optimum for sows farrowing at this time.

These factors together with the drawback of insufficient numbers in any month or year to smooth out random discrepancies, makes any such detailed study with the data available, impossible. However, this work is illuminating, and the fact that Haines suggests that the critical stage in the conditioning of percentage born alive is seven days before that conditioning birth weight, seems contrary to the logical sequence.

Whether or not, the results of Haine's work can be applied in its entirety to pigs can only be decided by actual experiment, but it may be mentioned that the guinea-pigs showed a similar relationship in mortality at birth, to age of dam and size of litter, as has been shown in the pigs. On the other hand, since Haines used a heated colony house, the significant stage in gestation may hold, while the extent of the possible variation may well have been masked by somewhat standardized conditions, and for this reason as well as the fact that the critical period in days may not be maintained in strict proportion to the ratio of 68 - 113 days in length of gestation period, the two species may quite easily differ.

When trying to apply the ideas derived from this guinea-pig work to the broad class intervals used in the presentation of the College data, it is obvious that the truth or otherwise of the results can hardly be tested.

The sows farrowing in the period April - July exhibit the highest percentage of dead born pigs. These sows may have been pregnant during December, January, February and March; or, April, May, June and July. These are the two extremes and they also represent two rather extreme sets of environmental conditions. However, most of the sows farrowing in this broad class were mated in March, April or May which is also the practice on most farms, so that farrowings are most frequent in July, August and September. (McMeekan 1937).

Sows mated in the months March and April will mostly farrow in June and July, and will experience a period of low temperatures and reduced feed supply for nearly all of their pregnancy period.

It thus becomes impossible to decide at which time, in the course of this pregnancy, factors were most effective in conditioning the percentage of still-born pigs, and until objective experiments under strictly controlled conditions can be devised to answer this question, one can only suggest that the practice of feeding sows on a satisfactory plane of nutrition only three weeks before parturition is probably of doubtful merit in reducing the percentage of still-births.

SEX RATIOS AND ASSOCIATED MORTALITY.

The preportion of males to females born among pigs is in itself, of no great importance except in so far as sex influences carcass quality. The position with pigs is somewhat different in this respect from that in dairy stock, where single births are the rule and the intensity of selection of milking stock is so dependent upon the sex ratio. In pigs the larger number born per litter enables selection for replacement stock to be carried out in a satisfactory manner without any great inconvenience being caused by extreme ratios of one sex to another.

On the other hand, pigs which are not needed for replacement stock in the breeding herd constitute the commercially valuable output of the farm's pig meat and it is, therefore, important to know to what extent sex ratios effect the number of pigs which are eventually sold, or more directly, the mortality rate.

In the College herd in 194 litters 52.68% of the pigs born were males. In actual numbers 845 males were born to 759 females, a difference which is significantly great when treated by the chi-square technique. Of the pigs born dead, 116 were males and 110 females, a difference which is not significantly great. For comparative purposes the figures quoted by other workers are listed in Table XXVII.

TABLE XXVII.

Sex ratios quoted by various authorities.

Authority.	% males born.	Males as a percentage of pigs born dead.
Lush, Hetzer and Culbertson (1934)	51.1	-
Krallinger (1931)	50.57	-
Husby (1933)	51.90	
Crew (1926)	50.0	
Sinclair and Syratuck (1928)	53.69	
McKenzie (1928)	51.0	55.0
Krizenecky (1935)	50.4	54.3
Carmichael and Rice (1920)	51.9	56.0
Present work.	52.68	51.32

Smith (1936) also quotes the results of several workers, but these are of the same order as those shown above.

Since the sex-ratio of stillborn pigs shows no significant excess of one sex over the other, it is of little value to explore the matter further with the limited data available. However, in view of the information given by various workers upon prenatal sex ratios in relation to prenatal mortality, and also observed ratios in inbred stocks, some discussion of these results is considered important not only in regard to mortality, but also in regard to fecundity.

Prenatal Sex Ratios and Differential Mortality.

Hammond (1921), Parkes (1925), Crew (1926) and

Warwick (1928) have all reported, as a result of examination of the uteri of pregnant sows, that the number of pigs born in any litter is dependent upon the number of eggs fertilised, and upon the number which develop to normal young. They found a discrepancy between the number of corpora lutea and the number of young in the uterus. Further results of Parkes and Crew indicate that not only is this foetal atrophy important in itself, but also it related to the sex ratio. Parkes observed the following sex ratios in relation to weight of foeti.

0 - 100 gms.	59.1 ± 1.98 % males
101 - 300 gms.	57.0 ± 3.12 % "
over 300	53.2 ± 2.45 % "

Parkes, therefore, postulates a primary sex ratio of 60:40 which is reduced to near equality in the course of gestation.

Crew's results were:

0 - 249 gms.	60.65 ± 1.08 % males
750 gms.	50.88 ± 1.82 % "

This very definitely leads to the conclusion that males are less viable <u>in utero</u> than are females and that as a result, prenatal mortality affects males more than females. The results of McKenzie (1928) and Carmichael and Rice (1920) in relation to the sex ratio of pigs born dead also supports this contention. (Table XXVII)

The Sex Ratios Observed in Inbred Stock.

Hayes (1921) and McPhee Russell and Zeller (1931) report a higher proportion of males in their inbred stock than in the controls. Litter size in both cases was reduced.

McPhee et alia give the following figures for a Chester White experiment.

Herd average	109.7 males to 100 females
1st generation of inbreeding	126.1 " " " "
2nd generation	156.0 " " " "

and these figures for Tamworths.

Herd average	128 males to 100 females
F_1 inbreeding	103 " " " "
F_2	124 " " " "
F_3	137 " " " "
F_4	180 " " " "

If these results are representative of the position in regard to sex ratios as a result of inbreeding, then the suggestion that inbreeding allows a segregation of lethal recessive factors, thus causing a greater prenatal mortality and a lowering of litter size, requires some qualification. One may well ask why, in an ordinary breeding programme the prenatal mortality is heaviest in the male sex, and yet when the effects of homozygous lethals are superimposed upon the supposed and probable lower viability of the males, as in inbreeding, the sex ratio in pigs born, actually indicates a distinct proportional increase in male survival.

If we accept the suggestion that in ordinary circumstances, males are less able to survive in a foetal community competing for a limited food supply, then a reasonable explanation may be, that, as the lethals would reduce the foetal population with equal sex incidence, and since by this means, the primary sex ratio would not be materially changed, the reduced competition resulting from the generally depleted numbers would allow for an equal chance of survival among the remaining foeti, and a sex ratio at birth similar to the primary one. It is suggested that the report of Hays, that the average birth weight of his inbred litters was greater than that of outbred stock, supports this view, though this increase in weight may simply be the result of the smallness of litters farrowed, which is a fairly general phenomenon.

In both cases cited above, however, litter size was reduced, but in experiments in which such a reduction did not result with close breeding, no mention is made of any unusual sex ratios. Had there been any such feature observed, it is felt that the fact would have been recorded, but in view of the lack of specific information on this point, what would be a valuable line of evidence, must lapse until such data are available.

Evidence supporting the contention that foetal atrophy may be dependent upon genetic factors has been reported by Hammond (1932) as a result of work with rabbits. In two inbred strains, both exhibiting low fertility, he found that the number of ova shed was 5 - 8 with 16 per cent of foetal atrophy in one strain, and in the other 11 ova shed with 83 per cent of foetal atrophy. He states that foetal atrophy appeared to be due to a recessive factor. Thus, while this supports the theory of autosomal recessives being responsible for reduced litter size in the pig it also suggests that some consideration must also be given to the possibility of reduction in the number of ova shed being responsible for some of reduction in litter size observed in inbred stock, although Willham's work (1938) in which he proved that litter size was restored in outcrossing inbred sows and boars does not give any support to this idea.

If, on the other hand, as Warwick suggests, genetic causes are the reason for foetal atrophy even in outcrosses, then the explanation of the fact that males are more severely affected becomes rather difficult. This would seem to indicate that a sex-linked recessive (one or a complex) was involved, but whereas such a condition would explain the heavier incidence of male mortality in outcrosses, it would hardly explain the survival of the males in inbreeding , unless autosomal lethals were postulated as the cause of reduction in litter size in the case of inbreeding, and further a threshold value, governed by environmental factors such as food supply were postulated in connection with the assumedly fairly common sex-linked lethal generally responsible for male mortality.

However, the sex linkage theory is open to question in that, if such a lethal were to be carried by a male and he was mated to a female hetrozygous for this factor, which is likely if the factor is widespread, then the proportion of sexes would revert, once again, to a primary ratio as equal numbers of males and females would then be affected, when the environment was such as to allow for the genetic threshold value to be passed. The question then arises, do various males mated at random exhibit in their offspring significant divergence from 50:50 ratios. Krallinger (1930) says that boars do show a difference in their progeny in this respect and as shown in Table 28 one boar in the College herd also sired significantly more males than females.

Table XXVIII.

The sex ratio of the progeny of 7 boars used in the College herd.

Boar.	Males.	Females.	Value x^2.
6105	70	62	
11314	81	73	
11206	119	104	
3913	89	65	3.74
9455	84	81	
5830	78	103	3.2
2824	113	83	4.6xxx

The fact that boar 2824 sired significantly more males than females, would, on the basis of the sex-linked lethal theory, indicate that he carried the lethal factor. If this were so, the litters which showed the greatest preponderance of males should then be smaller than those that contained equal numbers of males and females. However, it was found that the position, as shown in Table XXIX, was not as expected.

TABLE XXIX.

Litters sired by boar 2824, grouped according to their sex-ratios.

Preponderance of males.	Approximate equality of males and females.
8 litters	14 litters
71 pigs farrowed	125 pigs farrowed
22 females, 49 males	62 females, 63 males
8.8 pigs, average litter size	8.9 pigs.

The fact that the litters containing more males were not significantly smaller than those showing approximate equality does not lend any support to the above theory.

On examination of the litter size of litters sired by boar 5830, which exhibited an excess of females over males, a similar position is presented.

TABLE XXX.

Preponderance of females.	Approximate equality of males and females.
10 litters	12 litters
80 pigs farrowed	101 pigs farrowed.
59 females, 21 males	44 females, 57 males
8.0 pigs, average litter size	8.4 pigs.

It would have been reasonable to expect that litters in which females were in the majority would be ~~smaller~~ LARGER than those in which the sex ratio was near equality but the difference seen here is not even near significance, and this too is evidence contrary to the above theories.

It would be expected, on the basis of both of the suggested postulates, that the largest litters would, on the average, show a preponderance of males. Also a sow, which had been fed well before and after mating should experience a lower prenatal mortality rate among her offspring than one fed indifferently and this reduced mortality might be expected to produce two effects, firstly, the number born in such litters should be greater, and, secondly, since males are considered less viable than females, this reduced mortality resulting in increased litter size should effect male survival more than female survival, with a consequent rise in percentage of males born. For this reason the data for the whole herd were examined to see whether this was true.

TABLE XXXI.

Numbers of each sex born in litters of increasing size.

Litter Size.	Males.	Females.
3	19	14
4	13	11
5	26	29
6	65	60
7	88	73
8	96	88
9	165	150
10	97	93
11	120	100
12	90	66
13	19	20
14	40	44

The possibly of a higher percentage of males being born in large litters is refuted by Krallinger (1930), who states that the larger the litter the smaller the percentage of males, and this is supported by Machens (1951).

This fact is not upheld by the data from the College herd, as the only cases when the difference between the number born of two sexes approaches significance, are those relating to litter sizes of 11 and 12, where males are in excess. Again, it is only in the two widely separated litter sizes of 5 and 14 that females predominate and here the differences are extremely small. Thus, not only do the data in Tables XXX and XXXI tend to refute the conclusions of Krallinger and Machens but they also suggest a more complicated and delicate balance or genetic and environmental factors, as being responsible for prenatal mortality than that suggested here.

Parkes (1923) points out that since litter size is dependent upon two primary factors, first the number of ova shed and secondly, the number of young surviving from the conception to birth, it is not unusual that the litter size and sex-ratio of pigs born should show little relationship, because one factor influences the sex ratio and one does not.

It would seem, therefore, that the position in regard to prenatal mortality is still very obscure. Anomolous situations are frequent, and the recurring difficulty of distinguishing between environment and heredity calls for objective, controlled, experiments to decide more precisely the respective roles of these two factors. Statistical studies may throw some light upon the subject if the data are accurate and sufficiently extensive, but the work of Hammond, Crew, and Parkes, does not seem to sustain the results of such studies. No doubt, there is a point at which these lines of work can be made to coincide, but as yet, this remains a possibility and not an actuality. The studies of Jollos (1934), Goldschmidt, (1938), et alia, working with Drosophila Melanogaster have shown that there are stages in the life of the young when small environmental changes can produce a profound effect. With mammals these influences are no doubt "buffered" to some extent by the mother, but as Haines has indicated in his work with rodents environmental influences do exert a definitely measurable effect on various post-natal features, at various stages in the gestation period. When the variability in genetical constitution between breeds, strains, and even within litters, is superimposed upon this variability of external factors, both in point of time of incidence, and duration, as well as the differing susceptibility of the young organism to change as development proceeds, it is evident that though the basic problem may in the end prove to be relatively simple, the factors associated with it, mask, distort, and often apparently completely reverse the chain of circumstantial evidence upon which we have to rely at the present time.

SUMMARY.

Section 1.

(1) Length of gestation periods and factors affecting them.

The average length of gestation in the herd studied was 113.175 days with a standard deviation of - 2.03 days. This is similar to results obtained by other workers.

The factors treated were:-

(a) Ratio of Sexes, for which no coherent difference was found in the length of pregnancy of litters showing excess of either sex.

(b) Size of Litter, for which it was found that the larger litters were carried a significantly shorter time than small litters.

(c) Age of Sow, for which no constant relationship was observed between length of gestation and this factor.

(d) Season of Farrow, which was not found to exercise any significant effect upon the length of pregnancy.

(e) The possible effect of other factors is briefly discussed.

Section II.

Factors Influencing Prolificacy.

(a) The influence of interval between gestation periods upon subsequent litter size.

No significant influence of this factor was found in this study but the numbers in the classes treated were small and results must be accepted with caution.

(b) Relation of size of litter to age of dam.

While a trend, for litter size to rise up to the third litter, was evident from the data, no significant relationship could be established either when data relating to the whole herd were treated or only those relating to sows that had been in the herd for at least six litters. The possible effect of selection in distorting the results of other workers is discussed.

(c) <u>The influence of season of mating and farrowing upon litter size.</u>

The seasons or periods into which the data were divided were:- December to March (inc), April to July (inc) and August to November (inc). It was found that matings in December to March produced significantly larger litters than did matings in the other two periods, and August to November proved superior to April to July. No significance could be established between seasons of farrowing. The possibility of various environmental factors being respons--ible for the observed differences is discussed.

(d) <u>The influence of the boar on the size of litters sired by him.</u>

In keeping with other work on this subject no significant difference was found to exist between the size of litters sired by boars in reciprocal crosses. Data for this study were very limited.

(d) <u>The influence of the dam and sire upon the size of litters produced by their daughters.</u>

The study is preceded by a discussion of the efficacy of selection for greater prolificacy, the results of inbreeding and the light such results have thrown upon the mode of fertility inheritance.

The effect of selection for litter size in the College herd is examined and the influence exerted by four widely used boars is cited as illustrative of the necessity of including in selection programmes the sires in the herd as well as the dams. The influence of the dam was not studied in detail because of the small numbers of related sows available.

Section III.

Factors Influencing Mortality at Birth.

(a) The influence of the age of the sow.

It was found that mortality rate rose as the sows aged.

(b) Size of litter.

This factor was found to be significantly correlated with the percentage of still-births, the larger litters containing the larger percentage of dead pigs.

(c) The influence of season of farrow.

Periods treated were similar to those in Section II. It was established that farrowings in the period August to November were accompanied by fewer still-births than those in either of the remaining two periods. The period April to July produced the greatest percentage of pigs born dead. The various factors that may be responsible for this condition are discussed.

(d) Sex Ratios and Associated Mortality.

The results of various workers on pre-natal mortality and its sex incidence are discussed and theories suggested to explain these results, No support to any of these theories is produced by a treatment of the data from the College herd and the need for further research if the various evidence is to be reconciled, is stressed.

BIBLIOGRAPHY.

Bywaters, Culbertson and Hammond.
Am. Soc. An. Prdn. 1934. P.215.

Craft. Okl. Sta. Bien. Rept. 1925/26. Q
E.S.R. 57/521/1927.

Craft. Am. Soc. An. Prdn. 1931. P.265.
Royal Soc. Edin. Proc. 46. 1925/26.

Crew. E.S.R. 55/733/1926. Q

Dassogno. Indus. Latt. e Zootec 13. 1915. Q
E.S.R. 34/373/1916.

Davidson. J. Ag. Sc. 1930. P.262

Eckstaedt. Zuchtungskunde. 1928. Q
E.S.R. 60/727.1929.

Ellinger. Nat. Acad. Sc. Proc.
E.S.R. 46/73/1922. Q

Goldschmidt. Physiological Genetics 1938.

Hammond. Pig Breeders An. 1926. P.73.

Hammond. Farm Animals 1940.

Hammond. Proc. Int. Cong. Genetics. 1932. P.78.

Haring. Zuchtungskunde. Q
An. Breed. Abs. 1938.

Hays. Del. Sta. Bull. 1919. P.123. Q
E.S.R. 44/267/1921.

Haines. J. Ag. Res. 42/121/1931.

Henke. J. Hered. 26/455/1935.

Hetzer, Lambert and Zeller.
Circular 570. U.S.D.A. 1940.

Hodgson and Clarke.
Am. Soc. An. Prdn. 1934. P.212.

Hogan and McKenzie. Miss. Sta. Bull. 256. 1927. Q
E.S.R. 58/464/1928.

Hogan and McKenzie. Miss. Sta. Bull. 244. 1926. Q
E.S.R. 57/461/1927.

Hodgson. J. Hered. 1935.

Husby. 35 Beretn. Formgsforsokere Meldinger fra Norges
Landbrukshoiskole 1933.
An. Breed. Abs. 336/1934. Q

Hughes. J. Hered. 1933. P.199.

Jacobiec and Marchlewski.
Bull. Int. Acad. Polon. Sc. Lett. 1933. Q

Johansson. Red. Ultana. Landtbr. Inst. 1927. Q
E.S.R. 64/61/1928.

Johnson and Morrison. J. Ag. Res. 44/511/1932.

Jollos. Genetica. 1934.

Keith. J. Ag. Res. 41/593/1930.

Krallinger and Schott. Zuchtungskunde. 1933. Q
E.S.R. 71/459/1934.

Krallinger and Schott. Wiss. Arch. Landw. Abt.B. Arch. Tier.
u. Tierzucht. 26/1933.
E.S.R. 70/33/1934.

Krallinger. Zuchtungskunde. 1930 E.S.R. 65/527/1931. Q

Krizenecky. Sborn. csl. Akad. Zemed. 1938. Q
An.Breed. Abs. 1939.

Krizenecky. Sborn. csl. Akad. Zemed. 1935.
An.Breed. Abs. 1936. P.205. Q

Krizenecky. An.Breed. Abs. 1938. P.214.

Krizenecky. Sborn. csl. Akad. Zemed. 1935. Q
An.Breed. Abs. 1936. (quoted as 1938) P.204.

Kudrjavcev, Dimova and Grudev.
An. Breed. Abs. 1938. P. 305. Q

Lush, Anderson, Culbertson and Hammond.
Am. Soc. An. Prdn. 1933. P.282.

Lush, Hetzer and Culbertson.
Genetics. 1934. P.329.

Luthge. Zuchtungskunde. 1933. Q

Lush and Wentworth.
J.Ag. Res. 23/557/1923.

Lush and Molln.
Am. Soc. An. Prdn. 1937. P.133.

McKenzie.
Mis. Exp. Stn. Res. Bull. 118. 1928. (quoted as 1930)

McPhee and Zeller.
J. Am. Vet. Med. Assn. 1934. P.224.

McPhee, Russel and Zeller.
J. Hered. 22/393/1931.

McPhee.
Am. Soc. An. Prdn. 1930 P.131.

McPhee.
Am. Soc. An. Prdn. 1931. P.262.

Machens. Internat. Rev. Sci. and Pract. Ag. 1916. Q
E.S.R. 38/65/1918.

McMeekan. Recent pig keeping in New Zealand.
Reprint from N.Z. J. Ag. 1937.

Menzies-Kitchin. J. Ag. Sc. 27/624/1937.

Nordby. J. Am. Vet. Med. Assn. 27/911/1928/9.

Ostermayer. Sud. landw. Tierz. 1934. Q
An. Breed Abs. 1934. P.224.

Parkes. Ans. Appl. Biol. 10/287/1923. (quoted as 1925).

Parkes. J. Ag. Sc. 15/284/1925.

Parkes. Ztschr. Induktive. Abstam u. Berebungslekve. 1926.
E.S.R. 56/71/1927. Q

Podhradsky Sborn. csl. Akad. Zemed. 1938.
An. Breed. Abs. 1938. P.215. Q

Podhradsky. Sborn. csl. Akad. Zemed. 1937.
An. Breed. Abs. 1938. P. 215. Q

Ritzoffy. Zuchtungskunde. 1933.
E.S.R. Abstract. Q

Schmidt, Lauprecht and Staubesand. Zuchstungboil. 1936.
E.S.R. 78/180/1938. Q

Scott. 1938. N.Z. Dept. Ag. Bull. 167.

Smith. Pig Breed. An. 1930/1. P.46.

Smith. Robison and Bryant. Bib. Genetica. Reprint. 1936.

Sinclair and Syratuck. Sci. Ag. 8/ 1928.

Stutt. An. Breed. Abs. Dec. 1940. Q

Warwick. Wisconsin. Sta. Bull. 396. 1927.
E.S.R. 59/28/1928. Q

Willham. Am. Soc. An. Prdn. 1938. P. 304.

Zeller, Johnson and Craft.
Am. Soc. An. Prdn. 1937 P.121.

Zorn, Krallinger and Schott. 1933.
Zuchtungskunde.

Smith <u>et alia</u>:- Authorities quoted from this publication.

Axelson. (1928)
Pearl (1918)
Johansson (1929)
Wentworth and Aubel (1916)
Simpson (1912).
Funquist (1919)
Schmidt, Lauprecht and Vogel (1926)
Johansson (1931).

Morris and Johnson. J. Ag. Res. 44/511/1932.

Q - Abstracts read.

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