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THE EFFECTS OF NONGENETIC FACTORS ON RECORD OF PERFORMANCE (ROP) TEST RESULTS OF PIGS

BY

BRUCE BALDWIN ALLAN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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OF DOCTOR OF PHILOSOPHY

IN

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Date: July 23, 1985

DEDICATION

This thesis is dedicated to my father, Dr. John Donald Allan, whose wisdom and integrity have always provided inspiration.

ABSTRACT

The effects of nongenetic factors on Record of Performance (ROP) test results were examined in a data set comprising the records of 9679 ROP station tested boars. The records spanned a period from late 1975 to early 1979.

The development of pig testing in Canada and a description of the present day ROP program were provided to outline the principles and practices which constitute the ROP program. This was followed by a numerical description of the data set on hand.

An examination of potential sources of variation in the data indicated that contemporary groups (fill periods within a station and breed) and group sizes (singles, pairs and fours) differed significantly for certain performance traits. This made it necessary to accommodate this variation in subsequent analysis by restricting individual studies to particular subsets of the overall data set.

Heritabilities and genetic and phenotypic correlations derived from these data were in general accordance with literature estimates.

An examination of the effects of the pretest environment as indicated by weight, weight per day of age and variation in these traits among pen mates at the time of delivery to the test stations revealed that there were significant trends in average daily gain, feed conversion and performance index associated with weight at delivery. All three performance traits exhibited improvement as delivery weight increased. An increase in weight per day of age at delivery was associated with a decrease in the rate of growth between delivery and test commencement suggestive of compensatory gain.

An examination of the ROP backfat adjustment procedure was accomplished using "real" ROP data (i.e. as collected in the test stations and which provided a single backfat measurement) and a supplementary data set which provided sequential backfat measurements on individual boars. Both studies indicated that the present backfat adjustment procedure biased adjusted backfat values in favour of those boars which completed test heavier than 90 kg. The amount of bias inflicted by the adjustment procedure was dependent on the deviation in weight from 90 kg but could be as much as 21 index points over the range of acceptable terminal weights of 75 to 105 kg.

The ROP procedure for adjusting age to a standard 90 kg terminal weight was shown to be a relatively effective adjustment procedure.

An examination of alternate two trait selection indexes (comprising average daily gain and backfat) indicated that the additional genetic and economic progress possible from the inclusion of genetic and economic parameters in the index was negligible. The genetic selection index was shown to be highly robust over a wide range of economic weights, heritability estimates and genetic and phenotypic correlations.

The inclusion of halothane testing in the ROP program as a means of controlling stress problems was examined from a theoretical and practical standpoint. It was concluded that halothane testing lacks justification in the Canadian swine testing program. However, further examination of halothane sensitivity was suggested in terms of the possible exploitation of some of the beneficial characteristics associated with this condition.

The overall conclusion of this study was that there were nongenetic factors affecting the interpretation of ROP test results. Suggestions for accommodating some of these problems were presented.

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I. INTRODUCTION

The attainment of genetic improvement in livestock is contingent upon an accurate means for identifying animals of superior genetic merit to serve as progenitors of the next generation. Such identification is complicated by the fact that an indication of genotypic merit must be obtained indirectly from the measurement of phenotypic characters. The phenotype, however, represents the effects of both the genotype and the environment. Thus, accurate genetic comparisons between animals can be made only under standard environmental conditions.

Provision of a uniform environment was the primary reason for the incorporation of central test stations as part of the pig testing program in Canada. These facilities were founded on the premise that accurate between-herd comparisons could be made by eliminating the confounding effects of herd environments. Inherent in this was the assumption that the pretest environment (i.e. from birth to test commencement) exerted no influence on test performance. However, the limited amount of research which has been conducted in this area does not support this assumption.

The studies to be described in the following chapters were undertaken for purposes of examining the relationships between pretest and test performance of boars submitted to central ROP test stations. To this end, the raw data sheets of boars tested at record of performance (ROP) central test stations in Canada were obtained from ROP headquarters in Ottawa. These records contained data pertaining to the delivery of boars to the stations and when merged to master files which contained the pertinent test information yielded a data set conducive to the examination of pretest effects. However, as the study progressed it became evident that factors other than the pretest environment required study in order to address the central issue, namely the potential of the ROP system to fulfill its objective of unbiased genetic evaluation of pigs submitted for test. As a result, the study was expanded. The adequacy of age and backfat adjustments for terminal weight were examined using two data sets; the ROP data, in which each record contained a single backfat depth measurement, and sequential data, in which each record contained backfat measurements obtained at various weights. The latter data set made it possible to verify the conclusions drawn from examination of the standard ROP test records.

Other studies involved an examination of the relative merit of alternative procedures for indexing genetic merit and the potential impact on swine breeding programs of the recently inaugurated policy regarding halothane testing.

II. THE DEVELOPMENT OF THE CANADIAN ROP PIG TESTING PROGRAM

A. THE ROLE OF GRADING SYSTEMS IN PIG IMPROVEMENT

Pigs were first brought to Canada by early settlers, although the exact year of their introduction is not known. By 1871 the pig population in this country was estimated to be 1.4 million head (Fredeen 1965) and by 1900, 25 years after the inception of the first breed registries, there were 8 registered breeds (Fredeen 1980). The majority of these early registrations belonged to Yorkshires, Berkshires and Tamworths but the dominant role the Yorkshire breed subsequently assumed in Canadian pig production was already apparent by 1907 when this breed accounted for 53% of all registrations (Fredeen 1980).

In the formative years of the pig industry, production was concentrated in Ontario and Quebec. Thus, the type of pig raised was determined by local demand which, at that time, favoured pork high in fat (Fredeen 1965). However, this type of product was not conducive to development of a viable export market which pioneers of the industry felt lay in the export of bacon rather than pork. Though attempts were made to develop the bacon trade, they were hampered by several problems, not the least of which was the shortage of pigs of the desired type (Fredeen 1965). Rapid agricultural development of the western prairies also posed problems for export trade by creating a demand for pork of any type and thus thwarting attempts to develop a bacon type pig. Although the exports of Canadian pork to Britain increased sharply during the first World War, the short supply of quality bacon made Canada unable to compete for the lucrative British market once Denmark resumed exports in 1920 (Fredeen 1965). It was recognized, though, that the future of agriculture depended on a vigorous pig industry and that exports played a major role in the development of such an industry. Thus, in 1922 the first concerted approach to a national pig improvement program was initiated with the implementation of a live hog grading plan. Under the terms of this program a premium was paid for pigs meeting certain specifications of conformation and weight thought desirable for the production of bacon (Stothart 1937).

This grading plan was supplemented by carcass grading in 1937, and in 1944 the latter became the mandatory procedure for all hogs marketed in Canada (Fredeen 1965). This system of grading remained virtually unchanged until 1968 when it was replaced by an index which employed carcass weight and subcutaneous backfat measurements to predict the potential yield of trimmed retail product from the carcass (Fredeen 1984).

The impact of the national hog grading plans has been substantial in shaping the present industry. The early move to producing bacon type pigs has provided Canada with a quality product which fits in well with present consumer demand for lean meat. Between 1968 and 1982 alone, the grading system increased the yield of trimmed retail product by approximately 13 million kg (Fredeen 1984) by encouraging production of leaner carcasses. This had implications in both the feedlot, by reducing feed inputs, and the processing industry, by increasing the weight of trimmed retail product per unit of processing cost.

B. THE DEVELOPMENT OF PIG TESTING PROGRAMS

Shortly after the implementation of the first national grading plan in 1922 it was realized that more permanent pig improvement could only be assured through a plan relating to the breeding of pigs. Thus, in 1928, after extensive research of pig testing programs in other countries, the Joint Swine Committee initiated an experimental recording scheme at six Dominion Experimental Farms. Based on results of these initial trials, the "Advanced Registry Policy for Swine" was inaugurated in 1929 and testing was commmenced at 19 government experimental stations across Canada (Fredeen 1985). This program followed the lead of pig testing programs in the Scandinavian countries but was modified to suit Canadian conditions and the restrictions imposed by the great distances involved (Peterson 1938). In 1930 the policy was standardized and expanded to allow testing at producers' farms. Any purebred breeder with a boar and three or more sows could then apply to have his sows tested for eligibility for advanced registration.

The testing program in these early stages was a dam progeny test. Sows had to meet minimum requirements in each of three areas in order to qualify for an Advanced Registry number; prolificacy was measured in terms of number weaned while growth rate and carcass quality were measured on four littermates which were slaughtered at test completion. Boars obtained an Advanced registry number by siring three qualifying litters.

Station testing was incorporated into the program in 1934 to provide uniform test environments and to permit measurement of feed consumption of individual test litters. The first stations were established at New Hamburg, Ont., Saskatoon, Sask., Princeville, Que. and Charlottetown, P.E.I. Concurrent with the establishment of these facilities the home test aspect of the program was suspended. It was not until 3 years later, when test station space was fully subscribed, that home testing was reinstated (Fredeen 1985).

Though initially leasing test station space from private operators, the Department of Agriculture in 1937 constructed its own facilities at Saskatoon, Sask. and Edmonton, Alta. The justification for this move was to provide stricter control of the environmental conditions than was possible in the leased facilities (Lefebvre 1938). These two stations subsequently became the prototypes for those which were to follow.

Minor changes to the testing program occurred over the next three decades with the term "Record of Performance" (ROP) being added to the title in 1951 and fixed performance standards being replaced in 1960 by deviations from station-breed averages as a means of comparing tested litters.

In the late 1960's the ROP program adopted a policy of operating stations on an "all-in, all-out" basis to provide stricter health control. The larger stations were physically divided into smaller, more manageable sections with each section operating as an independent unit. This allowed the sections to be completely emptied and cleaned between fills. As each fill period was of 4 months duration this resulted in each section having 3 fills per year and allowed the sections to remain empty for approximately 2 to 6 weeks between fills. However, the implementation of all-in, all-out management was left to the discretion of the individual provinces and for this reason stations varied with regards to when the policy was adopted and the exact manner in which it was applied.

In 1969 the dam progeny test was replaced by a sire progeny test which involved testing four half-sib litters of two pigs each per boar (Fredeen 1985). However, studies initiated in 1966 to examine the feasibility of boar performance testing were rapidly generating support for this type of testing program and by 1969 gilts and boars were being performance tested on the home farm and central test stations were officially opened to boar performance testing in 1973. Interest in sire progeny testing steadily declined after this point and the last year of this type of test was in 1975 (Fredeen 1985).

The adoption of individual performance testing was made possible by the advent of the scalpel probe technique (Hazel and Kline 1952) and, later, ultrasonic techniques (Hazel and Kline 1959) which allowed backfat to be measured on the live animal and thus eliminated the need for slaughtering to provide an indication of backfat thickness. This type of testing provided several advantages over progeny testing. It not only increased the annual rate of genetic improvement which was possible from selection by decreasing the generation interval, but by eliminating slaughter tests it also increased potential selection intensity by providing a larger population from which to choose replacements (Fredeen 1966). Another advantage of individual performance testing was that traits which were to be included in a selection program could be measured directly on potential breeding stock rather than relying on indirect progeny measurements.

It was recognized that, to maximize the effectiveness of the program, performance testing should concentrate on those traits which would respond favourably to selection and which were of economic consequence to the industry. For this reason, growth rate as measured by average daily gain or adjusted age to test termination, feed efficiency in the form of feed to gain ratio and carcass quality in the form of backfat depth were chosen as the traits to be evaluated by performance testing. These traits have generally been reported to have moderate to high heritabilies with literature averages of 0.34 and 0.36 for average daily gain and feed conversion, respectively, and 0.48 for average backfat (Craft 1958; Smith and Ross 1965; Flock 1970; Rahnefeld 1970; Fredeen 1972; Young et al. 1978). Furthermore, experimental programs which have based selection on one or more of the aforementioned traits have reported that significant genetic improvement is possible (e.g. Hetzer and Harvey 1967; Fredeen et al. 1976; Standal 1979; Vangen 1979). On the other hand, maternal and reproductive traits are not included in the program as their low heritabilities (Fredeen 1972; Young et al. 1978; Vangen 1981) make them inappropriate to a performance test program aimed specifically at herds of relatively small size. Evidence of this is provided by the negligible results reported in the literature from experiments aimed at improving litter size using relatively low numbers of animals (e.g. Ollivier and Bolet 1982). These traits are, however, amenable to a progeny test approach applied in very large populations as illustrated by the favourable results of Bichard and Seidel (1982).

For the first few years following incorporation of performance testing into the ROP program, traits measured on test were reported individually. In 1976, genetic indexes (Hazel 1943) were incorporated into the program to provide a means of combining performance in several traits into a single index value. Average daily gain (ADG), feed to gain ratio measured on a pen basis (FC) and adjusted average backfat to 200 lb (ABF) were components of the station index while adjusted age to 200 lb and ABF were included in the home test index. In 1977 the ROP program was converted to metric with an accompanying change in the adjustment procedures and the indexes. Henceforth, age and average backfat were adjusted to 90 kg.

In 1980 FC was dropped from the station index and home and station indexes were revised to incorporate phenotypic parameters only. This move was supported by the research of Sather and Fredeen (1978) who reported significant correlated responses in FC from selection based on a phenotypic index incorporating only growth rate and backfat depth. The phenotypic index incorporated into the home test program was of the form:

$$\mathrm{INDEX} = 100 - 17.68[(\mathrm{X1}-\mathrm{MEAN}_{\mathrm{X1}})/\mathrm{SD}_{\mathrm{X1}}] - 17.68[(\mathrm{X2}-\mathrm{MEAN}_{\mathrm{X2}})/\mathrm{SD}_{\mathrm{X2}}]$$

while the index incorporated into the station test program was of the form:

$$\mathrm{INDEX} = 100 + 17.68[(\mathrm{X1}-\mathrm{MEAN}_{\mathrm{X1}})/\mathrm{SD}_{\mathrm{X1}}] - 17.68[(\mathrm{X2}-\mathrm{MEAN}_{\mathrm{X2}})/\mathrm{SD}_{\mathrm{X2}}]$$

where:

X1 = adjusted age to 90 kg in the home index and average daily gain in the station index

$\mathrm{MEAN}_{\mathrm{X1}}$ = contemporary group mean of trait X1 (i.e. all pigs of the same sex and breed which completed test in the previous 12 months)

$\mathrm{SD}_{\mathrm{X1}}$ = contemporary group standard deviation of trait X1

X2 = adjusted average backfat to 90 kg of the individual pig

$MEAN_{X2}$ = contemporary group mean of trait X2

SD_{X2} = contemporary group standard deviation of trait X2

17.68 was a multiplier to standardize the index to a variance of 625 (i.e. a standard deviation of 25).

Average backfat depth, obtained from the mean of four ultrasonic measurements (two on either side of the pig, 5 cm off the midline, at the midback region near the last rib and at the loin) was statistically adjusted to a standard terminal weight of 90 kg by assuming a linear pattern of backfat deposition with an intercept at zero weight and zero fat. Age values were adjusted to 90 kg by a procedure which based adjustment on instantaneous growth rates established for different weight and age groups (Fredeen, pers. comm.).

The most recent amendment to the program occurred in 1982 with the initiation of routine halothane testing of all boars entering the test stations. This action resulted from concerns regarding the porcine stress syndrome (PSS) and pale, soft, exudative pork (PSE) and their possible links to the "halothane gene" which was believed to be present in certain strains of Canadian pigs. From that time on, all boars which reacted positively when exposed to halothane gas were culled as were their full sibs. Though numbers of "reactor" boars are not reported, there is speculation that the program will be expanded to the home test portion of the program.

C. THE ROP PROGRAM TODAY

The ROP program as it exists today is officially titled "The Canadian Record of Performance (ROP) Swine Improvement Program". The primary objectives of the program are to provide pig producers with a means of identifying and ranking potential breeding stock according to their relative genetic merit and to provide a structure which will facilitate dissemination of genetic improvement throughout the industry. Also, although not an explicit objective of the program, ROP testing serves an important role in promoting both domestic and international sales of purebred breeding stock.

The home test aspect of the program is, for the most part, under the jurisdiction of the provincial departments of agriculture and accounts for 95% of all ROP testing activity. Testing is conducted under the supervision of an ROP technician and a producer enrolled in this program must submit for testing all potential breeding stock which reach 75 to 105 kg. At this time pigs are weighed, ultrasonically probed and indexed.

While the purpose of the home test program is strictly for within herd comparisons of potential replacement animals, the central test stations are used as a basis for making between herd comparisons. Unlike the home test aspect of the program, station tests involve only boars and are under the jurisdiction of the federal government.

Upon entering the test stations at weights between 18 and 30 kg, boars are penned in either groups of two (full sibs) or groups of four (two from each litter from the same sire). Each animal receives a minimum of 10 kg of a medicated pretest ration and when the average pen weight reaches the standard 30 kg starting weight, all pigs in the pen are placed on test. The test is terminated when the average pen weight reaches 90 kg at which time backfat depth, feed conversion and average daily gain are determined. Based on these results, the two trait phenotypic index (comprising average adjusted backfat depth and average daily gain) is calculated for each boar. The contemporary group definition used in construction of the station index has until recently been the rolling average of all boars of the same breed which completed test in the previous twelve months. However, at the present time some stations are in the process of converting to a "strict" contemporary group which includes only those boars completing test in the same section and fill period. At least eight pigs are required for contemporary comparisons. Subgroups with less than this number are not indexed.

Uniformity of testing conditions are maintained at the stations in several ways. A maximum weight of 30 kg at the time of submission to the station is intended to minimize the effects of the pretest environment while standardized rations within a station and standardized beginning and termination test weights insure that boars are tested under similar conditions. However, as tests are terminated based on average pen weight rather than individual weight, variation will exist in the weights at which boars are taken off test. Therefore, those traits which vary according to the liveweight at which they are measured must be adjusted to a standard terminal weight to allow accurate genetic comparisons. Thus both age and average backfat depth are statistically adjusted to 90 kg at the completion of test.

Boars completing test must meet minimum requirements set by the respective provincial ROP swine committees (usually 100 index) and be free of physical defects in order to be auctioned or returned to the breeder. Those not meeting these requirements are slaughtered. Sire evaluations are calculated for sires which have had an aggregate of one pair of station tested boars from each of four sows.

The numbers of boars which can be station tested annually are limited by station space. At present there are seven central test stations across Canada with the Nappan, Nova Scotia station serving the maritime region and the two Alberta stations serving Alberta and B.C. The other provinces have one station apiece. The combined capacity of these seven test stations is approximately 4000 boars. It is this limited testing capacity which has encouraged wide adoption of home testing and brought it to a position of dominance in the ROP program.

D. UTILIZATION OF THE ROP PROGRAM SINCE 1973

Since 1973, when performance testing was first incorporated into all aspects of the ROP program, numbers of home and station tests have increased steadily (Table II-1). The ceiling imposed by finite limits (i.e. numbers of stations and pens) has, of course, limited the growth of station testing activity. The last station constructed was the Leduc station in 1977 (Fredeen 1985) and the gradual increase in station tests since that time has resulted from more efficient use of space through such efforts as the remodeling of old facilities. However, the present numbers (approximately 4000) represent maximum station space and thus any future expansion will have to be in the home test aspect of the ROP program.

Testing activity from 1973 to 1982 was dominated by the Yorkshire breed with this breed in combination with the Landrace accounting for 81% of all station tests, 64% of all home boar tests and 47% of all home gilt tests in 1983.

An examination of regional proportions of breeds tested in 1983 revealed that while Yorkshire was the principal breed tested in the west and Ontario, Landrace were dominant in Quebec and the maritimes (Table II-2). In all provinces except Quebec (which tested no crossbred pigs) home tests of crossbred females outnumbered tests of any breed. Tests of the coloured breeds (i.e. Hampshire and Duroc) were of greatest proportions in Saskatchewan, Manitoba and Ontario while tests of Lacombes were confined principally to Saskatchewan and Alberta.

Manitoba exhibited a substantial decrease in its proportion of national tests over the 11 year period while Quebec and the maritimes registered moderate increases (Table II-3). The other stations remained fairly constant in terms of their proportion of total tests. Home tests, on the other hand, which are better indicators of regional participation as they are not limited by station space, revealed relatively constant test proportions of both gilts and boars over this period (Table II-4). Thus, while Table II-1 indicated that home tests increased substantially over this period, Table II-4 indicated that the increase was relatively uniform across the country.

Table II-1. Numbers of home and station tests by sex and year and the contribution (%) to total tests by Yorkshires, Landrace and crossbreds within sex and year+

		TOTAL TESTS		YORKSHIRE		LANDRACE		CROSSBRED		OTHER	
	YEAR	M	F	M	F	M	F	M	F	M	F
Station	1973	1603		43		23		1		33	
	1974	2169		41		26		1		[illegible]	
	1975	2688		46		25		3		[illegible]	
	1976	3044		48		24		4		[illegible]	
	1977	3239		49		23		2		[illegible]	
	1978	3203		48		29		[illegible]		[illegible]	
	1979	3733		46		33		[illegible]		[illegible]	
	1980	3712		49		30		1		20	
	1981	3673		47		32		2		19	
	1982	4004		49		33		1		17	
	1983	3857		48		33		2		17	
Home	1973	3800	6635	46	44	17	18	5	22	32	16
	1974	9206	17163	44	41	20	18	6	25	30	16
	1975	9432	18338	44	43	19	19	7	22	30	16
	1976	10954	23119	46	42	20	19	5	24	29	15
	1977	15069	30503	43	42	22	20	5	20	30	18
	1978	18065	38189	41	40	23	20	5	27	29	13
	1979	26218	62095	38	31	27	21	6	35	29	13
	1980	29593	72199	38	31	30	23	6	35	26	11
	1981	31573	76114	39	30	31	23	8	38	22	9
	1982	33315	81866	38	28	30	22	11	41	32	9
	1983	36436	89156	36	26	28	21	15	43	21	10

+adapted from Fredeen, 1985

M = male, F = female

Table II-2. Breed contributions (%), within province and sex, to total home and station tests conducted in 1983

	YORKSHIRE			LANDRACE			LACOMBE			HAMPSHIRE			DUROC			CROSSBRED			OTHERS		
	H		S	H		S	H		S	H		S	H		S	H		S	H		S
PROVINCE	M	F	M	M	F	M	M	F	M	M	F	M	M	F	M	M	F	M	M	F	M
B.C.	53	8	--	17	2	--	0	1	--	1	1	--	11	1	--	19	89	--	--	00	-
Alberta	42	33	71	11	8	11	11	6	9	3	2	4	5	2	4	28	49	1	0	0	0
Saskatchewan	36	20	47	12	8	13	39	23	12	3	1	7	7	4	13	3	44	0	0	0	8
Manitoba	43	25	49	12	5	21	3	1	1	8	2	7	7	3	13	13	55	5	14	0	4
Ontario	36	26	45	22	17	32	1	1	1	7	2	3	10	5	13	23	49	3	2	1	3
Quebec	28	36	41	53	54	48	2	1	1	9	5	4	8	4	6	0	0	0	1	1	0
Maritimes	38	24	31	43	33	58	2	1	2	2	1	3	5	2	5	5	36	1	5	3	0

H = home tests, S = station tests, M = male, F = female

Table II-3. Provincial contribution (%) to total station tests conducted within year

	PROVINCE					
YEAR	ALTA.	SASK.	MAN.	ONT.	QUE.	MARITIMES
1973	14	6	26	40	8	6
1974	13	8	21	38	12	8
1975	12	8	13	32	13	12
1976	21	8	12	33	15	11
1977	21	10	12	33	16	8
1978	22	7	9	38	16	8
1979	22	7	9	38	14	10
1980	26	8	9	35	13	9
1981	21	7	8	37	19	8
1982	23	6	4	36	17	14
1983	21	6	5	35	19	15

Table II-4. Provincial contribution (%) to total home tests conducted for each sex within year

	BOARS							GILTS						
YEAR	B.C.	ALTA.	SASK.	MAN.	ONT.	QUE.	MARI-TIMES	B.C.	ALTA.	SASK.	MAN.	ONT.	QUE.	MARI-TIMES
1973	1	15	10	7	39	21	7	1	11	4	5	39	27	3
1974	1	14	6	10	36	20	13	6	9	4	12	35	23	11
1975	1	13	8	12	42	12	12	5	13	6	13	38	13	12
1976	1	12	9	11	40	16	11	5	14	7	14	32	14	14
1977	2	12	9	9	37	21	10	5	13	7	9	34	18	14
1978	2	15	12	8	37	18	8	6	19	8	7	34	14	12
1979	2	14	9	7	34	24	10	5	15	8	8	35	16	13
1980	2	14	6	5	39	24	10	6	13	9	7	38	16	11
1981	1	14	7	5	38	26	9	7	13	9	5	40	16	10
1982	1	14	7	5	39	26	8	9	13	6	5	42	16	9
1983	1	15	7	5	38	25	9	8	12	5	5	44	16	10

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III. NUMERIC DESCRIPTION OF THE POPULATION

A. INTRODUCTION

The present chapter deals only with a numeric description of the data set obtained for the original purpose of examining the effects of the pretest environment. The pretest data comprised age and weights of pigs when delivered to the test station, age and weights at the start of test and pen totals for feed consumption between the time of entry to the station and the commencement of test. The test data comprised adjusted backfat, age and weight at test termination and the index of test performance calculated according to a three trait genetic index incorporating the traits average daily gain, feed conversion ratio and adjusted average backfat.

The population available for study was restricted to those boars for which pretest information was available. Such information does not appear in any reports issued by the ROP program and is not incorporated in the ROP data bank. Thus it was necessary to resort to the raw data records compiled for each pig by the ROP test station managers at the time pigs were submitted to the station. Such data sheets were obtained from the central office (Ottawa) for pigs entered on test during the years 1975 to 1979.

B. MATERIALS AND METHODS

The data from the pretest sheets were entered into a computer data bank which, after editing, was collated with the master ROP files for all pigs tested during the same period. These master files had been compiled at Lacombe by Milton Weiss during a period when Lacombe had the responsibility for developing a comprehensive computerized system for editing of ROP data, application of adjustments standardizing age and backfat to a constant terminal weight, producing individual boar reports and the preparation of annual summaries and sire progeny reports.

Individual pig numbers and herd identification (breeder tattoo number) provided the link between the two data sets (i.e. pretest and test). The computer records generated for each pig on the basis of this collation process included the following items:

(1) pig identity (tattoo, breeder number, sire and dam identification)
(2) dates of birth, entry to test station, start of test, disposal
(3) weights at entry to test station, start of test, disposal
(4) average daily gain in pretest period and on test, backfat measurements and adjusted average backfat to 90 kg at completion of test, adjusted age to 90 kg at completion of test
(5) feed consumption on a pen basis in the pretest period and on test
(6) three trait genetic index and rolling contemporary group averages (available only for data from 1977 and onwards)
(7) location of test (i.e. station, section, fill, pen no.)
(8) group size (i.e. number per pen)
(9) disposal information

The collation of the data banks for pretest and test was possible only for pens common to both. Thus any pens present in the pretest data which had no survivors to test termination (e.g due to mortality, failure to reach the specified termination weight, etc.) provided no basis for identifying location of test since these items of information (i.e. station, section, fill) were present only in the master ROP file.

The numeric structure of the residual population (i.e. after collation of pretest and test information) was evaluated by summarization of the frequencies associated with year and station of test, breed and breeder (herd of origin) and group size during test. An overview of breed differences in test performance was provided by summarizing the averages (across all stations) of deviations from contemporaries of the breed (i.e. deviation from station-year-section-fill averages). Culling ratios as deduced from differences between numbers submitted for test and numbers completing test were also estimated.

C. RESULTS

A total of nine test stations were represented in the data with the majority of the records (93%) covering tests performed during the period spanning 1976 to 1978 inclusive (Table III-1). The building of a new test station at Nappan, Nova Scotia resulted in tests at the old facility (Nappan #2) being phased out during this period and the new facility (Nappan #1) being brought on stream. Ontario was the province with the greatest number of tests (35%) followed by Alberta (with two stations) with 21% of the total tests. Yorkshires accounted for the majority of the tests (48%) followed by Landrace (26%), Duroc (12%), Lacombe (6%), Hampshire (5%) and the other minority breeds (Table III-2). Testing of crossbred boars accounted for only 2% of the total testing activity.

Performance means for average daily gain in kg (ADG), feed conversion ratio expressed as a pen average (FC), adjusted average backfat in mm (ABF) and adjusted age in days (AAGE) expressed as deviations from contemporary group averages, plus the trait averages, revealed that of the five principal breeds (Yorkshire, Landrace, Lacombe, Duroc, Hampshire), Lacombes exhibited the highest ADG and lowest AAGE, Durocs exhibited the lowest FC and Hampshires the lowest ABF (Table III-3). Hampshires exhibited the poorest performance in ADG and AAGE of these same five breeds, Landrace the poorest FC and Landrace and Lacombes the highest ABF.

The majority of boars (80%) began test in pens of two with a substantial number entered as fours (12%). The largest test group observed in these data was a single record of seven penmates (Table III-4). Pens which started test with odd numbers of penmates (i.e. singles and threes) presumably represented instances in which a boar was lost (died or was removed) from these test groups prior to the commencement of test.

The total number of individual breeders submitting boars for test during this period was 324. However, a large proportion of these (36%) submitted two or more breeds (Table III-5). Thus, defining "breeder" as a breed within herd increased the number of breeders to 494. Defined this way, the majority of breeders (47%) tested fewer than 10 boars during the period covered by these data (Table III-6). The three eastern-most stations were well below the rest of the country in average numbers of boars tested per breeder with few breeders testing more than 20 boars during the period covered by these data. It is not known whether this was indicative of a dearth of large breeders in this region or to lack of participation in the ROP program.

Culling rates for each station and breed were obtained by summing the numbers of boars which died or were removed before completion of test and those culled at the end of test but before indexing (Table III-7). The three western-most stations appeared to have had considerably lower culling rates than the other stations for all breeds. The exception was the extremely high rate of 50% for the Hampshire breed at Saskatoon but this was a function of the small number (only four) of Hampshire boars tested. Lacombe boars and crossbreds appeared to have had the lowest culling rates but in the case of Lacombes this observation may be partially confounded with location as 70% of the Lacombe boars were tested in the three western-most stations. However, within each of these three stations the culling rates of the Lacombe boars were below the station averages. Most of the testing of crossbred boars (78%) occurred at the New Hamburg station and within this station the culling rate applied to these boars was well below all other breeds.

D. DISCUSSION

The preceding enumerations indicated that any analysis of this data set would be complicated by the many potential sources of variation while the unbalanced nature of the data and the resulting confounding of effects (e.g. breed and pen size in station) would make statistical adjustment of doubtful relevance. For these reasons, in the studies which follow, the analyses were restricted to subclasses of the overall data set which provided adequate numbers of observations for meaningful analyses yet minimized extraneous variation.

The restrictions applied varied according to the nature of each particular study but all analyses were restricted to one or more of the three principal breeds (Yorkshire, Landrace, Duroc). Further restrictions applied in certain of the studies pertained to size of the station-breed subgroup and contemporary group (fill period with breed, station and year) as well as the pen group size.

Table III-1. Numbers of boars tested by station and year

	YEAR ENTERED TEST STATION					
STATION	1975	1976	1977	1978	1979	TOTAL
Charlottetown	38	104	130	110	--	382
Nappan #1	--	145	84	91	2	322
Nappan #2	44	80	22	--	--	146
Lennoxville	110	451	562	392	4	1519
New Hamburg	184	988	1201	1006	--	3379
Brandon	62	364	383	250	2	1061
Saskatoon	94	276	338	108	--	816
Lacombe	62	294	318	264	--	938
Leduc	60	314	388	352	2	1116
Total	654	3016	3426	2573	10	9679

Table III-2. Numbers of boars tested by station and breed

	STATION									
BREED	CHARLOTTE-TOWN	NAPPAN #1	NAPPAN #2	LENNOX-VILLE	NEW HAMBURG	BRANDON	SASK-ATOON	LEDUC	LACOMBE	TOTAL
Yorkshire	158	130	55	615	1328	576	472	758	600	4692
Landrace	160	156	71	551	1173	112	78	70	102	2473
Lacombe	6	-	-	54	28	98	152	150	120	608
Hampshire	16	8	5	88	339	23	4	18	16	517
Duroc	40	26	15	211	350	214	110	102	78	1146
Crossbreds	-	-	-	-	154	2	-	18	22	196
Tamworth	-	-	-	-	3	-	-	-	-	3
Chester White	2	2	-	-	2	-	-	-	-	6
Berkshire	-	-	-	-	-	18	-	-	-	18
Spot	-	-	-	-	2	-	-	-	-	2
Managra	-	-	-	-	-	18	-	-	-	18

Table III-3. Performance trait averages (with standard errors in parenthesis) by breed

BREED	PERFORMANCE TRAIT + ADG	FC	ABF	AAGE
Yorkshire	0.863 (0.002)	2.505 (0.003)	15.76 (0.04)	149.9 (0.2)
Landrace	0.866 (0.002)	2.600 (0.004)	17.17 (0.05)	148.2 (0.3)
Lacombe	0.890 (0.004)	2.559 (0.006)	17.17 (0.11)	143.1 (0.5)
Hampshire	0.852 (0.004)	2.568 (0.078)	15.06 (0.10)	152.4 (0.6)
Duroc	0.885 (0.003)	2.486 (0.005)	16.05 (0.07)	149.8 (0.4)
Tamworth	0.897 (0.033)	3.060 (0.057)	23.86 (1.16)	176.0 (6.2)
Crossbred	0.902 (0.007)	2.486 (0.015)	16.07 (0.15)	144.1 (0.8)
Chester White	0.766 (0.063)	2.708 (0.076)	16.44 (0.57)	160.0 (5.5)
Berkshire	0.831 (0.030)	2.703 (0.050)	14.93 (0.59)	162.0 (2.5)
Spot	0.738 (0.005)	2.496 (0)	11.81 (0.15)	146.2 (3.0)
Managra	0.880 (0.019)	2.616 (0.042)	16.16 (0.60)	158.8 (2.3)

+ deviation from contemporary group mean + trait average

Table III-4. Numbers of boars tested by station and group size

STATION	NUMBER IN PEN 1	2	3	4	5	6	7
Charlottetown	--	340	18	24	--	--	--
Nappan #1	--	250	36	36	--	--	--
Nappan #2	--	76	24	28	5	6	7
Lennoxville	2	498	3	1016	--	--	--
New Hamburg	443	2936	--	--	--	--	--
Brandon	--	752	216	88	5	--	--
Saskatoon	--	816	--	--	--	--	--
Lacombe	--	938	--	--	--	--	--
Leduc	--	1116	--	--	--	--	--
Total	445	7722	297	1192	10	6	7

Table III-5. Numbers of breeders testing different numbers of breeds

NUMBERS OF BREEDS TESTED					
1	2	3	4	5	TOTAL
208	75	32	5	4	324

Table III-6. Numbers of breeders testing different numbers of boars over the period of study

STATION	NO. BOARS TESTED 1-9	10-19	20-29	30-39	40-49	50-59	60+	TOTAL	AVE. # BOARS PER BREEDER
Charlottetown	28	9	3	2	--	--	--	42	9.1
Nappan #1	20	4	4	1	1	--	--	30	10.7
Nappan #2	16	5	--	--	--	--	--	21	7.0
Lennoxville	34	28	13	6	7	--	2	90	16.9
New Hamburg	95	37	20	9	6	6	11	184	18.0
Brandon	38	18	6	3	5	1	2	73	15.4
Saskatoon	18	8	7	1	5	--	2	41	19.9
Lacombe	24	15	5	3	4	--	4	55	17.0
Leduc	32	14	10	4	1	--	5	66	16.9
All Stations+	233	108	55	25	25	14	34	494	19.6

+ the station totals do not sum to this row as some breeders tested at more than one station

Table III-7. Culling rates (as % of total boars entered) by breed and station

	BREED							
STATION	YORKSHIRE	LANDRACE	LACOMBE	HAMPSHIRE	DUROC	COMMERCIAL	OTHERS+	ALL BREEDS
Charlottetown	5.7	6.9	0	6.2	0	--	0	5.5
Nappan #1	3.8	3.8	--	0	7.7	--	0	4.0
Nappan #2	5.4	4.2	--	0	0	--	--	4.1
Lennoxville	7.6	5.1	9.2	10.2	3.8	--	--	6.4
New Hamburg	7.0	4.4	3.6	6.2	2.9	1.3	12.5	5.3
Brandon	6.9	3.6	2.0	0	4.2	0	5.6	5.4
Saskatoon	4.7	0	2.5	50.0	2.7	--	--	3.8
Lacombe	1.7	1.0	0.8	0	1.3	0	--	1.4
Leduc	1.6	0	0	0	2.0	0	--	1.3
All Stations	5.1	4.2	2.0	6.4	3.1	1.0	6.4	4.5

+ Tamworth, Chester White, Berkshire, Spot, Managra

IV. SOURCES OF VARIATION AMONG ROP STATION TESTED BOARS

A. INTRODUCTION

The previous chapter identified various potential sources of variation present in the ROP test station population. The objective of this study was to examine the effects of those sources of variation on test performance. Year, section and fill were examined to determine whether consistent trends existed in the population with respect to these effects and to determine to what degree contemporary groups differed within station and breed. Analysis of group size effects was undertaken to determine to what extent pig performance was influenced by group size (i.e. boars tested as singles, pairs and fours). Genetic and phenotypic parameters were derived for the two principal breeds represented in the ROP population (Yorkshire and Landrace) while a detailed tabulation of a representative station-breed subclass was provided to indicate the structure of the population from which these parameters were derived.

B. MATERIALS AND METHODS

For analysis of year, section and fill (season) the data set was reduced to minimize the number of missing (zero frequency) subclasses. This objective required restricting the population to two breeds in two provinces for three years, 1976, 1977 and 1978. Furthermore, only those boars tested in pens of two in which both penmates completed test were included in the analysis. The three station-breed subclasses utilized were: (1) Yorkshires and (2) Landrace tested at the New Hamburg, Ontario station and (3) Yorkshires tested at the Leduc, Alberta station. Numbers of observations in each subclass were 976 in the Ontario Yorkshire subclass (YONT), 936 in the Ontario Landrace subclass (LONT) and 734 in the Leduc Yorkshire subclass (YLED).

A contemporary group was defined as a year-section-fill subgroup within each station-breed subclass. There was a potential of 36 such contemporary groups in the YONT and LONT subclasses (4 sections with 3 fills each per year) and 18 possible contemporary groups in the YLED subclass (2 sections with 3 fills each per year). Contemporary group sizes ranged from 2 to 54, 10 to 46 and 4 to 60 in the YONT, LONT and YLED subclasses, respectively (Table IV-1). While all 18 contemporary groups were present in the YLED subclass, there was one missing contemporary group in the YONT subclass and two in the LONT subclass. For the purposes of analysis, two estimated observations derived on a within station-breed subclass basis were inserted into each missing cell. In the YONT subclass the two estimates were: (1) the mean of all observations in fill #3 in 1978 and (2) the mean of all observations in section #4 in 1978. In the LONT subclass the mean of all observations in fill #3 in 1978 was inserted into both missing cells as one estimate while the mean of all observations in section #1 in 1978 was inserted into the missing cell in section #1 as the second estimate in this cell and the mean of all observations in section #4 in 1978 was inserted into the missing cell in section #4 as the second estimate in this cell.

The completed station-breed subclasses were then analysed separately by analysis of variance using the fixed model:

$$Y_{ijkl} = u + R_i + S_j + F_k + RS_{ij} + RF_{ik} + SF_{jk} + RSF_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = performance of the l^{th} boar in the k^{th} fill of the j^{th} section of the i^{th} year

u = overall mean

R_i = effect of the i^{th} year

S_j = effect of the j^{th} section

F_k = effect of the k^{th} fill

RS_{ij} = interaction between the i^{th} year and the j^{th} section

RF_{ik} = interaction between the i^{th} year and the k^{th} fill

SF_{jk} = interaction between the j^{th} section and the k^{th} fill

RSF_{ijk} = interaction between the i^{th} year, the j^{th} section and the k^{th} fill

e_{ijkl} = random error

The performance traits included in the analysis were average daily gain in kg (ADG), feed to gain ratio on test as measured by pen averages (FC), adjusted average backfat to 90 kg in mm (ABF) and adjusted age to 90 kg in days (AAGE).

The data subset used to derive heritabilities and genetic and phenotypic correlations was restricted to the two main breeds and included only those contemporary groups containing more than 25 boars. These restrictions resulted in a total of 4130 boars consisting of 3183 Yorkshires and 947 Landrace.

Heritabilities and genetic correlations were derived from a nested analysis of variance defined by breeders, sires within breeders, dams within sires and progeny within dams (error). To avoid confounding with station, year, section and fill effects, performance traits were expressed as deviations from contemporary group averages where a contemporary group was defined as a breed-station-year-section-fill subclass. The model for this analysis was:

$$Y_{ijkl} = u + B_i + S_{ij} + D_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = the performance (ADG, FC, ABF, AAGE) of the lth boar within the kth dam within the jth sire within the ith breeder expressed as a deviation from the contemporary group average

u = overall mean

B_i = effect of the ith breeder

S_{ij} = effect of the jth sire within the ith breeder

D_{ijk} = effect of the kth dam within the jth sire within the ith breeder

e_{ijkl} = random error

The variance components thus derived were used to estimate paternal half-sib heritabilities by the equation (Falconer, 1981):

$$h^2 = 4v_S^2 / (v_S^2 + v_D^2 + v_W^2)$$

where:

h^2 = paternal half-sib heritability

v_S^2 = sire component of variance

v_D^2 = dam component of variance

v_W^2 = full sib component of variance

Genetic correlations were derived by the equation (Falconer, 1981):

$$r_G = \mathrm{Cov}_{XY} / (v_X^2 . v_Y^2)^{0.5}$$

where:

r_G = genetic correlation between traits X and Y

COV_{XY} = sire component of covariance for traits X and Y

v_X^2, v_Y^2 = sire components of variance for traits X and Y

To examine the effects of omission of breeder effect on heritability values, these parameters were also calculated from variance components derived from a nested analysis of variance in which the breeder effect was excluded. The model for this analysis was:

$$Y_{ijk} = u + S_i + D_{ij} + e_{ijk}$$

where the terms in the model are as previously described.

Standard errors for heritability estimates and genetic correlations were derived from the method described by Dickerson (1969).

A phenotypic correlation matrix was constructed from the Pearson product-moment correlation coefficients between respective pairs of traits i.e.:

$$r_P = SCP_{XY} / (SS_X . SS_Y)^{0.5}$$

where:

r_P = phenotypic correlation coefficient

SCP_{XY} = sum of cross products of trait X and Y

SS_X, SS_Y = sum of squares of traits X and Y

The structure of the population from which the genetic and phenotypic parameters were derived was examined by tabulating progeny and dam numbers per sire and breeder for Yorkshire boars tested at the New Hamburg station.

Group size differences were examined by comparing boars tested as pairs or fours at the Lennoxville station and boars tested as singles or pairs at New Hamburg. These were the only two stations in which sufficient numbers were present in the different group sizes for meaningful analysis. In addition, analyses were restricted to Yorkshire and Landrace boars. This resulted in a total of 2204 Yorkshire boars and 838 Landrace boars available for analysis (Table

IV-2). In each breed and station, performance variables were expressed as deviations from the contemporary group mean with only those groups containing more than 10 boars being included in the analysis. As observations were expressed as deviations from contemporary group, breed effects were not expected to be significant (i.e. deviations summed to zero within breed, station, year, etc.). However, this effect was included in the model to provide an indication of the magnitude of the interaction between breeds and group sizes. The model was:

$$Y_{ijk} = u + B_i + Z_j + BZ_{ij} + e_{ijk}$$

where:

Y_{ijk} = performance (ADG, FC, ABF, AAGE) of the kth boar in the jth group size of the ith breed expressed as a deviation from the contemporary group average
u = overall mean
B_i = effect of the ith breed
Z_j = effect of the jth group size
BZ_{ij} = interaction between the ith breed and the jth group size
e_{ijk} = random error

C. RESULTS

Year effects were significant ($P<0.01$) for all traits and in all subclasses except for ADG in the YONT and YLED subclasses. Section and fill effects were not significant ($P>0.05$) for ADG in any of the subclasses while the probability levels for these two effects varied considerably among the other three traits (FC, ABF, AAGE) and among the subclasses (Table IV-3).

Examination of the least squares means of these traits indicated that very few traits exhibited consistent change over time in any of the subclasses (Table IV-4). The only consistent favourable trend observed was in the YLED subclass in regards to ABF. Although the Ontario subclasses exhibited lower ABF in 1978 compared to 1976, this was interrupted by an increase in ABF in 1977 in both subclasses. Similar trends were observed in regards to FC in these two subclasses. ADG exhibited a significant ($P<0.05$) decline in the LONT subclass while AAGE exhibited a significant ($P<0.05$) increase in the YONT and LONT sublclasses. Two and three way interactions were significant for most traits and subclasses (Table IV-3).

The variance components for breeder, estimated from a model including this effect, varied considerably among breeds and traits ranging from zero to 13.8% in the Landrace and 4.5% to 11.0 % in the Yorkshires (Table IV-5). Degrees of freedom for each effect were approximately three times as large in the Yorkshire breed as in the Landrace breed (Table IV-6).

Heritability estimates and genetic and phenotypic correlations derived from these data were in general agreement with those reported in reviews of the literature (e.g. Craft 1958; Smith and Ross 1965; Rahnefeld 1970; Young et al 1978) (Table IV-7).

Heritabilities derived from a model excluding the breeder effect were generally greater than those derived from a model including this term (Table IV-8).

Examination of Yorkshire boars tested at the New Hamburg station, which represented 34% of the data used in the genetic analysis, indicated a large degree of confounding of breeder and sire (Fig.

IV-1) with 33% of all breeders being represented by a single sire. Although the overall average number of sires per breeder was 3.4, 26% of all the sires were submitted by 4 (5%) breeders whose test boars comprised 24% of all the boars tested over the time span of these data. While the average number of progeny per sire was 4.4, 13% of all the boars tested were provided by 4 (i.e. 2%) of the sires represented (Fig. IV-2). There was also a high degree of confounding of dams with sires as 51% of all sires were represented by a single dam (Fig. IV-3).

Group size effects were significant (P<0.01) for ADG and FC at the New Hamburg station and for FC and AAGE at the Lennoxville station (Table IV-9). Least squares means indicated that, for both breeds at New Hamburg and for the Yorkshires at Lennoxville, the boars in larger groups exhibited significantly (P<0.05) lower FC (Table IV-10). While these differences were not significant (P>0.05) in the Landrace at Lennoxville, the same trend was apparent. Boars tested individually at New Hamburg exhibited significantly greater (P<0.05) ADG than those tested as pairs and while boars tested as pairs had higher ADG than those tested as fours at Lennoxville, this difference was not significant (P>0.05). However, more rapid growth in terms of lower AAGE was evident (P<0.05) in the boars tested as pairs at Lennoxville compared to those tested as fours. Interactions between group size and breed were not significant for any of the traits at the New Hamburg station but were significant (P<0.01) for FC and AAGE at Lennoxville. However, for both traits the interactions arose from variation in the margin of difference between breeds rather than from a reversal in ranking.

D. DISCUSSION

Examination of year effects did not indicate that there was consistent improvement in any of the traits studied. However the period covered by these data was too short to establish definite time trends in performance.

The observation that neither section nor fill effects were significant ($P>0.05$) in the LONT subclass with regards to any of the performance traits while the YONT subclass exhibited significant ($P<0.05$) effects of both section and fill in regards to FC, ABF and AAGE was difficult to interpret as both these breeds were tested contemporaneously in all subclasses in the Ontario station. However, significant interaction effects in the YONT subclass indicated that the section and fill effects were not consistent in relation to each other or to years. Quite possibly, breeder differences between contemporary groups could have accounted for apparent differences, rather than any real seasonal or section differences. Significant ($P<0.05$) interactions were also observed in the YLED subclass in regards to FC, ABF and ADG indicating that in this subclass, also, section and fill effects were not consistent from year to year or among sections and fills.

Thus, while it must be concluded that year, section and fill effects did not exhibit any consistent trends in any of the three subclasses studied, there were, nonetheless, significant differences among contemporary groups for certain of the performance traits.

The variance components derived for breeders include both environmental and genetic effects. Unfortunately, these effects are confounded and cannot be estimated in the absence of information pertaining to the relationship of parents within the herds. However, the results for the Yorkshire boars agree well with those of Jonsson and King (1962) who reported estimates for breeding centre effect in Danish Landrace pigs of 7.3%, 4.4% and 7.9% for ADG, FC and ABF, respectively. Upon removal of the genetic component, these authors (Jonsson and King 1962) reported the variation in ADG, FC and ABF associated with breeding centre environment to be 5.5%, 1.4% and 6.0%. Similar analysis by Jonsson (1965) reported variance components associated with breeding centre environment for these same traits to be 8%, 8% and 2%, respectively. Therefore, although generally small, breeder effects represent an important source of variation which should be taken into account in any genetic analysis. This was apparent in the present study by the inflated heritability estimates derived from a model which excluded breeder effects. In such a model, variation due to breeder was manifested in the sire component of variance and thus inflated the paternal half sib heritability estimates.

The relatively large standard errors associated with the genetic parameters derived in the present study can be attributed to the unsuitabilty of the data for genetic analysis. Robertson (1959) suggested that 20 to 30 individuals per half sib family are desirable for meaningful genetic analysis which is well above the 4.4 average found in the ROP population studied in this analysis. The large degree of confounding of sires in breeders, stations and years as well as the confounding of dams in sires is further indication that genetic parameters derived from this type of data must be interpreted with caution.

The analyses of group size effects tended to suggest that increasing pen density was accompanied by reduced growth rate and improved FC. The observation that there was no significant interaction of breeds with group size in regards to boars tested as singles versus pairs while this interaction was present in the analysis of pairs versus fours may indicate that the differences in performance between singles and pairs is more pronounced than the differences between pairs and fours. Possibly this relates less to penning density per se than to behavioural responses characteristic of boars tested in isolation.

Table IV-1. Contemporary group sizes in the three subclasses analysed for year, section and fill effects

		1976			1977			1978		
		FILL			FILL			FILL		
SECTION	SUBCLASS	1	2	3	1	2	3	1	2	3
1	YONT	18	20	14	28	22	34	34	48	2
	LONT	14	36	16	46	28	34	36	28	★
	YLED	40	38	34	32	46	60	36	48	42
2	YONT	10	20	24	22	28	42	24	32	30
	LONT	14	16	18	18	24	24	28	34	34
	YLED	36	38	30	30	40	50	38	48	4
3	YONT	10	16	26	16	30	54	24	26	34
	LONT	20	34	14	30	34	24	22	36	24
	YLED	–	–	–	–	–	–	–	–	–
4	YONT	38	24	20	48	18	32	20	40	★
	LONT	20	28	24	20	10	28	22	44	★
	YLED	–	–	–	–	–	–	–	–	–

★ missing (zero frequency) cell

Table IV-2. Numbers of boars by breed and station utilized for analysis of group size effects

STATION	BREED	GROUP SIZE 1	2	4	Total
New Hampshire	Yorkshire	165	974	--	1139
	Landrace	133	932	--	1065
	Total	298	1906	--	2204
Lennoxville	Yorkshire	--	168	260	428
	Landrace	--	126	284	410
	Total	--	294	544	838

Table IV-3. Probability levels of year, section, fill and interaction effects for the three station-breed subclasses from analysis of variance of the performance traits

	YONT				LONT				YLED			
SOURCE	ADG	FC	ABF	AAGE	ADG	FC	ABF	AAGE	ADG	FC	ABF	AAGE
Year	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.01	0.00
Section	0.50	0.02	0.05	0.01	0.06	0.12	0.94	0.18	0.14	0.64	0.03	0.06
Fill	0.24	0.00	0.04	0.00	0.87	0.13	0.61	0.32	0.30	0.00	0.97	0.54
YearxSection	0.00	0.00	0.02	0.00	0.85	0.08	0.35	0.07	0.00	0.00	0.35	0.00
YearxFill	0.02	0.00	0.00	0.00	0.06	0.01	0.00	0.05	0.34	0.00	0.00	0.00
SectionxFill	0.23	0.00	0.00	0.00	0.82	0.00	0.00	0.16	0.04	0.01	0.01	0.99
YearxSectionxFill	0.14	0.00	0.00	0.00	0.03	0.02	0.00	0.08	0.10	0.04	0.01	0.00

Table IV-4. Least squares means (with standard errors in parenthesis) of the performance traits by station-breed subclass and year

TRAIT	STATION-BREED SUBCLASS	YEAR 1976	1977	1978
ADG	YONT	0.84 (0.01)	0.82 (0.01)	0.83 (0.01)
	LONT	0.86 b[+] (0.01)	0.84 a (0.01)	0.83 a (0.01)
	YLED	0.88 (0.01)	0.87 (0.01)	0.88 (0.01)
FC	YONT	2.53 b (0.01)	2.60 c (0.01)	2.49 a (0.01)
	LONT	2.64 b (0.01)	2.66 b (0.01)	2.58 a (0.02)
	YLED	2.46 a (0.01)	2.52 b (0.01)	2.47 a (0.01)
ABF	YONT	14.2 b (0.1)	14.4 b (0.1)	13.3 a (0.2)
	LONT	14.8 a (0.1)	15.8 b (0.1)	14.3 a (0.2)
	YLED	17.3 a (0.2)	17.1 a (0.2)	16.4 b (0.3)
AAGE	YONT	151.0 a (0.8)	154.2 b (0.6)	155.4 b (1.1)
	LONT	146.4 a (0.8)	150.3 b (0.7)	151.7 b (1.1)
	YLED	143.7 a (0.8)	149.9 c (0.8)	146.8 b (1.2)

[+] values in the same row with different letters are significantly different ($P<0.05$)

Table IV-5. Variance components as percentages of total variation in performance for Yorkshire and Landrace boars

TRA	BREED	BREEDER	SIRE	DAM	ERROR
ADG	Yorkshire	5.2	7.3	13.9	73.6
	Landrace	0^+	14.0	17.3	68.6
FC	Yorkshire	4.5	13.3	58.7	23.5
	Landrace	0.1	7.1	76.1	16.8
ABF	Yorkshire	6.4	7.2	26.4	60.0
	Landrace	13.2	4.8	25.4	56.7
AAGE	Yorkshire	11.0	8.7	26.0	54.2
	Landrace	13.8	11.3	29.1	45.8

+ negative variance components were set to zero

Table IV-6. Degrees of freedom and coefficients of expected mean squares (k values) for the estimation of components of variance

SOURCE	BREED	d.f.	ERROR	DAMS	SIRES	BREEDERS
Breeders	Yorkshire	174	1.0	2.3	6.0	18.0
	Landrace	54	1.0	2.1	5.7	16.4
Sires	Yorkshire	411	1.0	2.1	5.2	--
	Landrace	124	1.0	1.9	5.1	--
Dams	Yorkshire	907	1.0	2.1	--	--
	Landrace	313	1.0	1.9	--	--
Error	Yorkshire	1690	1.0	--	--	--
	Landrace	455	1.0	--	--	--

Table IV-7. Heritabilities and genetic correlations (with standard errors in parenthesis) and phenotypic correlations between performance traits⁺

	YORKSHIRE				LANDRACE			
		FC	ABF	AAGE	ADG	FC	ABF	AAGE
ADG	1 (0)	-0.35**	0.22**	-0.72**	0.56 (0.19)	-0.40**	0.14**	-0.72**
FC	-0.54 (0.20)	0.56 (.15)	0.14**	0.26	-0.82 (0.41)	0.28 (0.24)	0.11**	0.25**
ABF	0.12 (0.22)	0.28 (0.20)	0.31 (0.11)	0.18**	0.01 (0.36)	-0.70 (0.55)	0.22 (0.18)	-0.05
AAGE	-0.73 (13.94)	0.21 (4.09)	-0.14 (2.66)	0.39 (0.11)	-0.26 (32.18)	0.71 (29.80)	-0.45 (18.89)	0.52 (0.21)

⁺ heritabilities on diagonal, phenotypic correlations above, genetic correlations below

** P<0.01

Table IV-8. Heritabilities (with standard errors in parenthesis) from sire components of variance with and without breeder effect in the model

TRAIT	BREED	HERITABILITY WITH BREEDER	HERITABILITY WITHOUT BREEDER
ADG	Yorkshire	0.31 (0.10)	0.51 (0.09)
	Landrace	0.56 (0.19)	0.55 (0.16)
FC	Yorkshire	0.56 (0.15)	0.62 (0.13)
	Landrace	0.28 (0.24)	0.39 (0.21)
ABF	Yorkshire	0.31 (0.11)	0.54 (0.10)
	Landrace	0.22 (0.18)	0.73 (0.18)
AAGE	Yorkshire	0.39 (0.11)	0.76 (0.10)
	Landrace	0.52 (0.21)	0.92 (0.19)

Table IV-9. Probability levels for breed, group size and interaction effects from analysis of variance of the performance traits in Yorkshire and Landrace boars tested at the New Hamburg and Lennoxville test stations

SOURCE	STATION	ADG	FC	ABF	AAGE
Breed	New Hamburg	0.24	0.59	0.30	0.32
	Lennoxville	0.69	0.91	0.91	0.46
Group Size	New Hamburg	0.00	0.00	0.40	0.56
	Lennoxville	0.49	0.00	0.44	0.00
Interaction	New Hamburg	0.16	0.53	0.36	0.27
	Lennoxville	0.24	0.01	0.31	0.00

Table IV-10. Least squares means (with standard errors in parenthsis) of the performance traits, expressed as deviations from the contemporary group averages, of breeds, group sizes and interaction (breed x group size)

		NEW HAMBURG				LENNOXVILLE			
SOURCE	EFFECT	ADG	FC	ABF	AAGE	ADG	FC	ABF	AAGE
Breed	York	0.005	0.017	0.02	0.1	0.003	-0.003	-0.00	-0.4
		(0.004)	(0.007)	(0.09)	(0.05)	(0.005)	(0.006)	(0.14)	(0.5)
	Land	0.012	0.012	0.16	-0.6	0.000	-0.004	-0.02	-1.0
		(0.004)	(0.007)	(0.10)	(0.5)	(0.005)	(0.007)	(0.15)	(0.5)
Group Size	1	0.018a+	0.040a	0.22	-0.4	-	-	-	-
		(0.006)	(0.009)	(0.12)	(0.7)				
	2	-0.002b	-0.011b	-0.04	-0.1	0.004	0.016a	0.06	-2.1a
		(0.002)	(0.004)	(0.05)	(0.3)	(0.006)	(0.008)	(0.16)	(0.6)
	4	-	-	-	-	-0.001	-0.022b	-0.09	0.7b
						(0.004)	(0.006)	(0.12)	(0.4)
Interaction	York x 1	0.010	0.045a	0.10	0.3	-	-	-	-
		(0.008)	(0.012)	(0.16)	(0.9)				
	York x 2	-0.001	-0.011b	-0.05	-0.1	0.001	0.030a	-0.03	-0.7
		(0.003)	(0.005)	(0.07)	(0.4)	(0.008)	(0.010)	(0.22)	(0.8)
	York x 4	-	-	-	-	0.005	-0.035b	0.02	-0.2
						(0.006)	(0.008)	(0.17)	(0.6)
	Land x 1	0.026a	0.034a	0.35	-1.2	-	-	-	-
		(0.008)	(0.014)	(0.18)	(1.0)				
	Land x 2	-0.003b	-0.010b	-0.03	0.0	0.007	0.003	0.16	-3.5a
		(0.003)	(0.005)	(0.07)	(0.4)	(0.009)	(0.012)	(0.25)	(0.9)
	Land x 4	-	-	-	-	-0.007	-0.010	-0.21	1.5b
						(0.006)	(0.008)	(0.17)	(0.6)

+ effects within source in the same column with different letters are significantly different ($P<0.05$)

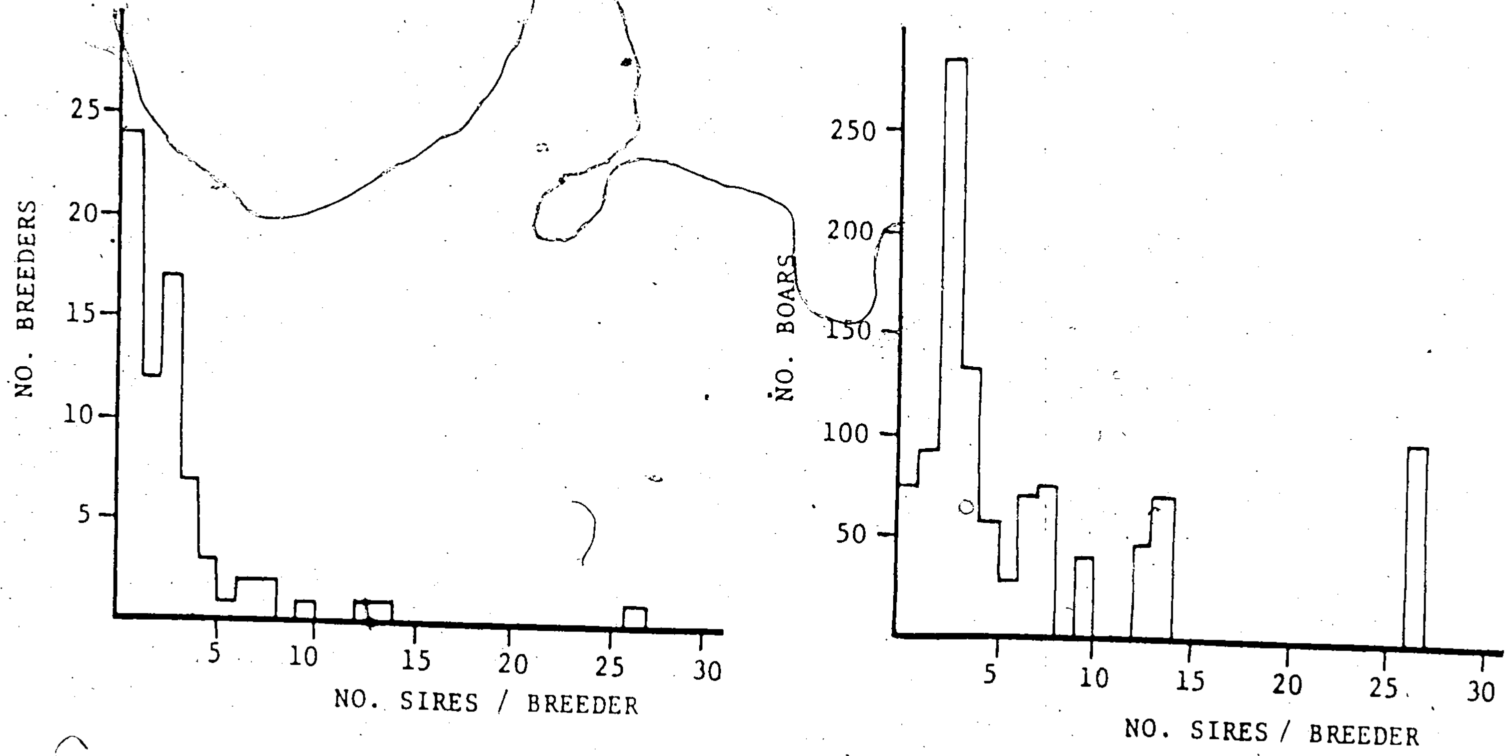

Fig. IV-1. Numbers of Yorkshire breeders and boars represented by various numbers of sires over a three year period at the New Hamburg test station.

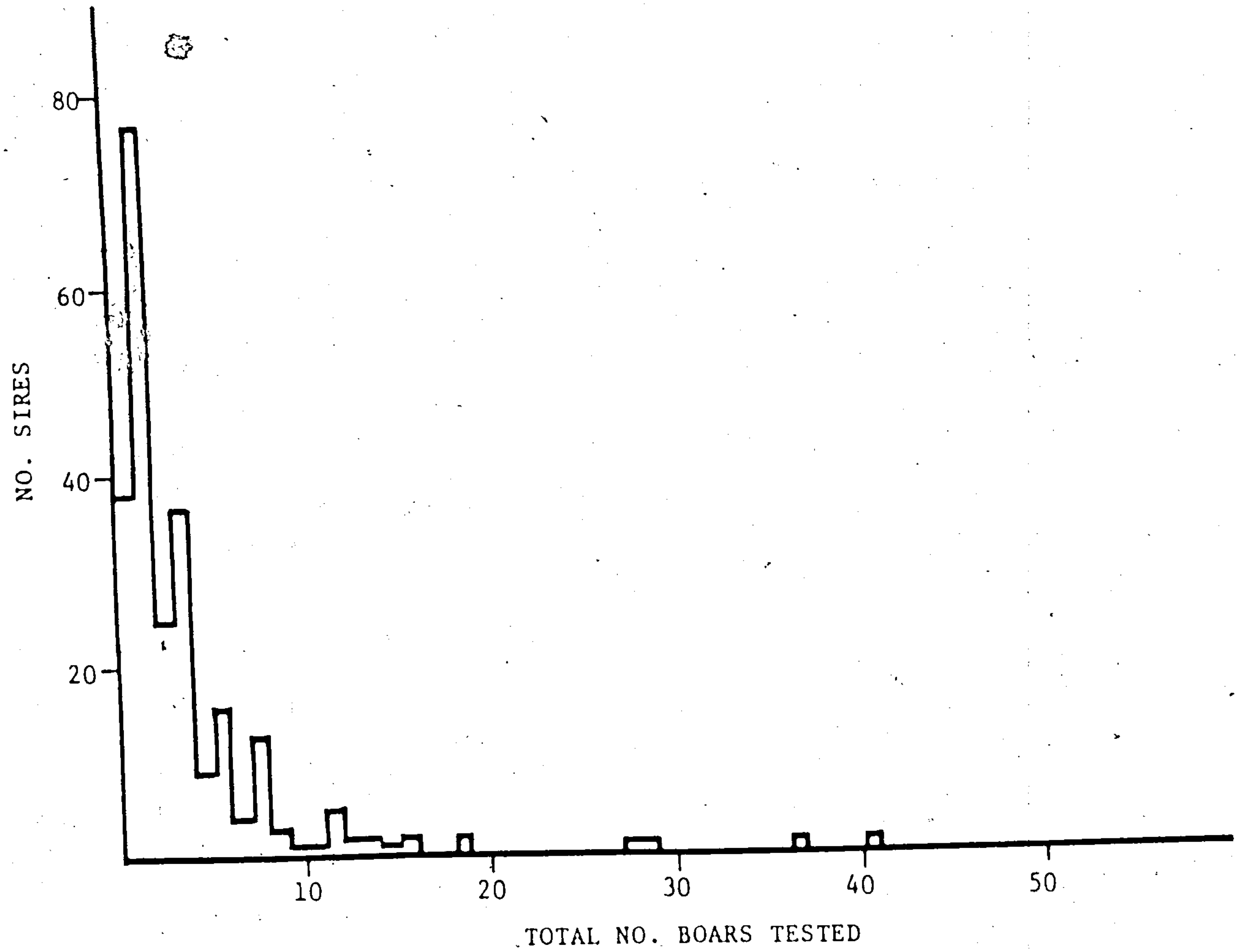

Fig. IV-2. Numbers of Yorkshire sires represented by various numbers of boars over a three year period at the New Hamburg test station.

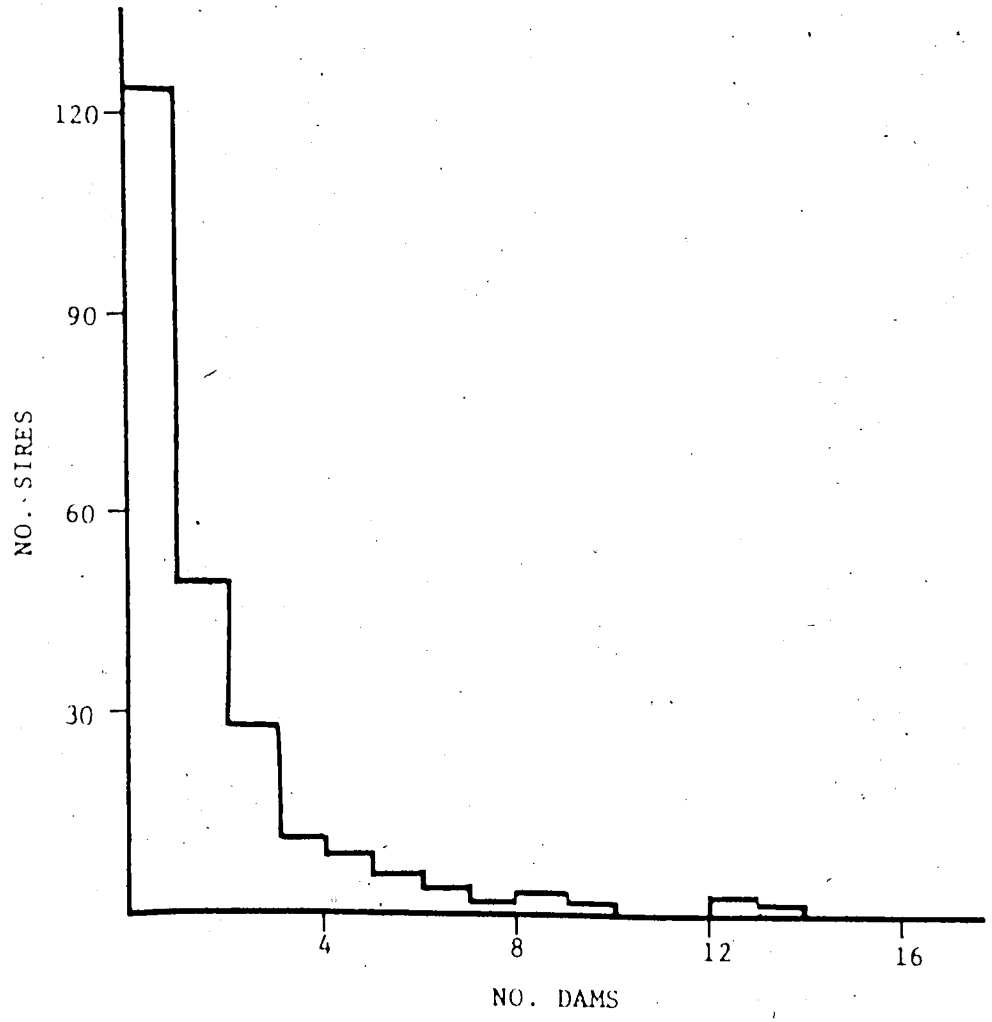

Fig. IV-3. Numbers of Yorkshire sires represented by various numbers of dams over a three year period at the New Hamburg test station.

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V. THE EFFECT OF DELIVERY CRITERIA ON SUBSEQUENT RECORD OF PERFORMANCE (ROP) TEST STATION PERFORMANCE

A. INTRODUCTION

Weaning and nutritional regimes prior to testing have been demonstrated to have substantial effects on subsequent test performance. Lucas et al. (1959) reported that pigs weaned at 56 days of age and fed ad lib. until 22.7 kg exhibited 7 to 8% more rapid growth and 7 to 9% better feed efficiency from 23.2 to 93.2 kg than pigs weaned at 10 days of age and fed ad lib. to 22.7 kg even though both groups of pigs had similar ages at 22.7 kg liveweight. The superiority in both traits ($P<0.01$) was maintained in the latter stage of the test period (46.4 to 93.2 kg) as well as in the earlier stage (23.2 to 46.4 kg). [illegible] he same study, two groups of early weaned pigs subjected to feed restriction prior to testing demonstrated that increasing degrees of restriction resulted in superior rates of growth and feed efficiency ratios on test. This superiority was most apparent in the early stage of the growth period (23.2 to 46.4 kg). However, regardless of the degree of restriction, the early weaned pigs were not superior in either trait to the pigs weaned at 56 days of age.

Boaz and Elsley (1962) similarly reported that pigs which were subjected to greater degrees of feed restrictions after weaning exhibited superior rates of growth and feed conversion ratios from 22.7 to 90.9 kg compared to those subjected to less severe restriction. The effects of feed restriction were greater in early weaned pigs (i.e. weaned at 4.5 kg) than those weaned at 56 days but these authors did not observe any significant effects of weaning regime per se on either growth rate or feed conversion although the values for the pigs weaned at 56 days were slightly superior.

Webb and King (1979) compared the test performance of groups of boars, barrows and gilts weaned at three, five and eight weeks of age. Their results indicated that boars weaned at eight weeks of age were significantly superior to those weaned at three weeks of age in average daily gain, feed conversion and index for economy of production, and significantly inferior for liveweight at 50 days. With regards to barrows and gilts, these weaning regimes produced significant differences only in liveweight at 50 days. Pigs weaned at 5 weeks of age were intermediate in performance and in most cases were not significantly different from either the three or eight week treatments.

In contrast to these findings, Skjervold and Standal (1964) reported that pigs weaned at five weeks of age had significantly (P<0.05) greater growth rates on test than those weaned at eight weeks of age. Although these latter two studies appear to contradict each other, there are other factors involved which may partially explain the discrepancies.

Webb and King (1979) reported that the early weaned pigs (three weeks) were significantly (P<0.05) younger at start of test (27 kg) than those weaned at eight weeks. The authors concluded that this probably reflected a larger intake of nutrients to this point. Skjervold and Standal (1964), on the other hand, reported that early weaned pigs (5 weeks) were significantly older (P<0.10) at the start of test (20 kg) than those weaned at 8 weeks. It would appear, then, that the postweaning environment had different effects in these two studies. The common element in both studies, however, was that the pigs on the weaning regime which produced the lowest rate of growth (weight per day of age) at test commencement subsequently exhibited significantly superior average daily gain and feed conversion during the test period.

In the studies by Lucas et al. (1959) and Boaz and Elsley (1962), the pigs which exhibited the lowest weight per day of age at test commencement (the feed restricted groups) subsequently exhibited superior rates of gain on test. However, the restricted groups also exhibited higher ages at test completion indicating that average daily gain calculated from birth to test completion (i.e. age at test completion) was not comparable to that calculated during the test period. Lifetime average daily gain contained pretest environmental influences and therefore was not a reliable estimate of feedlot growth.

Three of the above studies (Boaz and Elsley 1962; Skjervold and Standal 1964; Webb and King 1979) reported no differences in carcass merit among treatments while Lucas et al. (1959) reported that early weaned pigs exhibited greater deposition of body fat. These latter results, however, must be viewed in light of the low numbers of animals involved (18 pigs per treatment).

The reports in the literature pertaining to the influence of the pretest environment indicate that some form of compensatory growth may be operating in those animals exhibiting reduced growth rates up to the start of test. If this is indeed so, then feed restrictions applied at the home farm could bias the interpretation of results of boars submitted for test at central test stations.

The role of central boar test stations is to provide a uniform environment in which boars from different herds may be compared. The program operates on the principle that a uniform environment will minimize the variation associated with nongenetic factors and thus improve the precision with which genetic differences may be estimated. It is of primary importance, then, that the pretest environment either exerts no effect on test performance or that any influence the pretest environment may exert is negated by an adjustment period upon entering the test station prior to starting test. However, the "warm-up" period that the ROP program provides for boars entering test stations will vary in length depending on the average weight of the pen at delivery. In fact, groups of boars submitted close to the 30 kg starting weight may be put on test immediately and therefore be deprived of any "warm-up" period at all.

The only information available at the time of submission of boars to the test stations which might be indicative of the pretest environment are weight at entry (INWT) and age at entry (INAG) both of which are subject to manipulation by the breeder. INWT expressed as a ratio of INAG gives an indication of the rate of predelivery growth, or weight per day of age at the time of delivery (i.e. predelivery growth [PGTH] = INWT/INAG), and is the trait which would be affected by feed restrictions in the pretest environment.

The objective of this study was to determine whether the pretest environment as indicated by INWT and PGTH had any effect on test station performance and whether variation between pen mates in relation to these delivery traits bestowed any advantage on the lighter or heavier pigs in a pen in terms of test performance.

It is not unreasonable to postulate that breeder opportunities to control INWT would be related to distance from the test station. Thus, breeders within a few miles of the station would experience little inconvenience in delivering boars at a desired weight whereas breeders quite a distance from the station would be more likely to coordinate delivery of boars with other errands. This would tend to result in a more random weight distribution of boars at delivery among breeders at greater distances. Therefore, another objective of this study was to examine whether there were differences due to the distance of breeders from the test station (DIST) in terms of INWT or the time of submission of boars relative to other pigs in the fill period (FILL) and the subsequent effects of INWT and FILL on weight at test termination (FNWT). The consistency with which breeders delivered boars at particular weights or weights per day of age was also examined.

B. MATERIALS AND METHODS

The data for this study comprised the records of boars from three station-breed subclasses; Yorkshires (YONT) and Landrace (LONT) from the New Hamburg station and Yorkshires (YLED) from the Leduc station. Only the records of boars tested as full-sib pairs and those from contemporary groups containing more than 25 boars were included in the analyses (Table V-1).

In order to pool the records of all boars within a station-breed subclass, all performance variables (i.e. average daily gain in kg [ADG], feed:gain ratio expressed as a pen average [FC], adjusted average backfat in mm [ABF] and the three trait genetic index [INDEX]) were expressed as deviations from the contemporary mean (i.e., year-section-fill within station-breed subclass).

Relationships between delivery variables (INWT, PGTH, variation (WTVR) in INWT among pen mates and variation (GRVR) in PGTH among pen mates) and performance variables (ADG, FC, ABF, INDEX) were examined by coding pens into discrete classes based on pen averages of each of the four delivery variables and calculating performance variable means for each class. The use of pen averages reflected the policy of the ROP program by which test decisions are made on a pen, rather than an individual, basis.

PGTH was coded into six classes according to increments of 0.5 standard deviation (SD) units with class 1 encompassing all values less than -1.0 SD below a mean derived from the overall data set comprising 4452 Yorkshire boars and 2368 Landrace boars and class 6 encompassing all values greater than 1.0 SD above the mean. In this way class 1 and 6 represented true extremes in delivery criteria. The other traits were also coded into six classes each but with coding based on actual values. INWT was classified by increments of 2.0 kg, GRVR by increments of 0.01 kg/day difference between pen mates and WTVR by increments of 1.0 kg difference between pen mates (Table V-2).

The exception to the use of pen means was in a study to determine whether the heavier sib at delivery (or faster growing) had an advantage over the lighter (or slower growing) sib. This analysis was different from the one described previously in which the variation of INWT between penmates (WTVR) was examined for its effect on average pen performance. In this analysis boars were classified into six groups according to the deviation in weight from their pen mate

WTDV). Class 1 included all boars which were more than 4 kg lighter than their penmate at delivery with subsequent classes covering 2 kg increments of INWT deviations up to class 6 which included all boars which were more than 4 kg heavier than their penmate. Thus the classes were symmetrical about zero as a pen containing a boar in class 6 would also, by definition, contain a boar in class 1. Classes 1, 2 and 3 contained the lighter boars from each pen while classes 4, 5 and 6 contained the heavier penmates. Analysis was performed on individual records rather than pen averages with the means for the performance variables (ADG, ABF, INDEX) calculated for each WTDV class. FC was not included in the analysis as this trait was expressed on a pen basis and, therefore, individual values were not available.

Means of the "delivery" traits (INWT, PGTH, WTVR, GRVR, WTDV) which appeared to exhibit trends relative to the performance traits based on examination of the class means were plotted to allow visual appraisal of these trends. Simple regression analyses were used to determine whether observed trends were significant (i.e. significance of the regression coefficient) and the amount of variation in the test variable explained by the delivery variable (R^2). The model used for analysis was:

$$Y_i = b_0 + b_1 X_i + e_i$$

where

= average pen performance, or boar performance in the analysis of WTDV, in terms of ADG, FC, ABF and INDEX expressed as deviations from the contemporary average

X_i = means of the delivery variables INWT, PGTH, WTVR, GRVR, WTDV

b_0 = Y intercept

b_1 = regression coefficient of Y_i on X_i

e_i = random error

In order to examine the effects of PGTH on growth rates immediately after submission of boars to the station, mean growth rates in the pretest period (PADG) were calculated for each coded level of PGTH for those boars which had pretest periods (i.e. "warm-up" periods) of more than four days. PADG was regressed on PGTH to quantify this relationship.

The effect of distance from the test station on INWT and FILL was examined in the YONT and YLED subclasses by coding pens according to the distance of the breeder's home town (km) from the test station (DIST) and calculating the means of INWT and FILL for each DIST class. Distances were coded differently in the two subclasses due to differences in the number of breeders in each subclass (Table V-3). The effects of INWT and FILL on FNWT were examined by calculating means of FNWT for each INWT class and FILL day.

The consistency with which breeders tended to deliver boars at a particular weight or rate of growth was examined by ranking the breeders in each of the three station-breed subclasses according to the average INWT and PGTH in 1976 and comparing this ranking to the INWT and PGTH of these same breeders in 1977 and 1978. For this analysis the data were restricted to those breeders testing in all three years (1976 through 1978, inclusive).

C. RESULTS

The means of all traits examined with regards to coded levels of INWT, PGTH, WTVR, GRVR, WTDV, FILL and DIST are presented in the appendix.

ADG, FC and INDEX exhibited definite trends relative to INWT in each of the three station-breed subclasses (Fig. V-1). The upward trend in INDEX as INWT increased can be explained by the fact that two of the component traits, ADG and FC, showed favourable trends while the third, ABF, showed no response.

Although the regressions of ADG, FC and INDEX on INWT were significant in two of the three subclasses, the amount of variation in the performance traits explained by variation in INWT was very small in each case and did not exceed 4.0% (Table V-4). However, because the signs of the regressions were consistent in all three subclasses, being positive for ADG and INDEX and negative for FC, these relationships were probably indicative of real effects.

Examination of the coded levels of PGTH (Fig. V-2) revealed no consistent trends although INDEX appeared to increase in the two Yorkshire subclasses as PGTH increased. Only two regressions were significant with regards to PGTH and as the signs of the coefficients were not consistent among subclasses these regressions were not regarded as being indicative of real trends (Table V-5).

There were definite trends apparent in PADG relative to PGTH (Table V-6). In all subclasses there was a noticeable decline in PADG associated with an increase in PGTH (Fig. V-3). The regression of PADG on PGTH was significant at the 5% probability level in the YONT and LONT subclasses and at the 10% probability level in the YLED subclass

(Table V-7).

Examination of the means for the coded levels of WTVR and GRVR indicated that there were no trends in the mean pen performance relative to variation between pen mates in INWT or PGTH. The large standard errors (Appendix Tables 3 and 4) indicated that all but a few of the coded levels were not significantly different from zero (the contemporary group average).

The distribution of observations in each of the coded levels of WTVR indicated that the majority of penmates were delivered within 2 kg of each other (65%, 66% and 61% in the YONT, LONT and YLED subclasses, respectively). Thus the distribution for this trait was skewed with relatively few observations in the higher classes. GRVR also appeared to be skewed with the majority of penmates tending to be similar with regards to this characteristic, but the variation was greater than that of WTVR.

The trends in individual performance relative to WTDV revealed that only ADG appeared to exhibit any consistent trends (Fig. V-4). Although INDEX appeared to exhibit a slight upward trend with regards to variation of INWT, the large standard errors (Appendix Table 5) indicated that these trends were of no real significance. A regression analysis of ADG on WTDV (Table V-8) indicated that although the trends were significant ($P<0.05$) the variation explained by this trait was negligible.

Distance of breeders from the test station did not appear to affect the weight at which boars were delivered but did appear to be related to FILL (Fig. V-5). At the Leduc station, especially, breeders close to the station appeared to deliver their pigs relatively early in the fill period compared to those greater distances from the station.

In all three subclasses there was a definite increase in FNWT as INWT increased (Fig. V-6). This was especially apparent in the YONT subclass where the two lightest classes of boars at delivery had mean final weights well below the 90 kg target terminal weight. The trend was not as noticeable in the LONT subclass and even less so in the YLED subclass where all boars except those in the lightest INWT class reached close to the target terminal weight. An examination of the trends in FNWT (Fig. V-7) relative to FILL revealed that there did appear to be a downward trend in FNWT relative to fill (ignoring the last classes in each station-breed subclass which had low numbers). The trend was most apparent in the YONT subclass.

An examination of the consistency with which breeders tended to deliver boars (Fig. V-8 to V-13) indicated a great deal of variation in the ranking of breeders from year to year in all three subclasses with respect to both INWT and PGTH. The greatest degree of consistency was observed in respect to PGTH in the LONT subclass in which the ordering of breeders in regards to this trait was relatively constant over the three years (Fig. V-11).

D. DISCUSSION

The only consistent relationships between delivery and performance traits observed in this study were the favourable relationships between increasing INWT and ADG and FC on test. Quijandria et al. (1970), Neville et al. (1976) and Drewry (1979) also reported significant ($P<0.01$) regressions of ADG and FC on initial weight. The first study did not indicate the sign of the regressions but the last two reported positive regressions of ADG on initial weight, which were in agreement with those found in this study, while the regressions of FC on initial weight in both studies were reported to be positive, in contrast to those found in the present study. Initial weight as reported in those studies differed from that in the present study in that those studies considered weight at start of test rather than weight at delivery to the station. Thus the results are not directly comparable to those reported here. The effects of initial weight have also been noted in cattle (Moore et al. 1961; Schalles and Marlowe 1967; Batra and Wilton 1972; Wilton et al. 1973; Tong 1982) with these studies reporting improved performance in terms of ADG on test associated with higher entry weights.

One possible means by which the observed relationship between INWT and performance could arise is by INWT affecting the interpretation of ADG through its association with FNWT. The observed relationship between INWT and FNWT suggested that groups of pigs which were below average in weight at delivery were terminated early as a means of clearing out the fills which were of determinate length. Therefore, if the measurement of ADG was related to the weight at which it was obtained, there would be a relationship between FNWT and ADG. Further, since INWT affected FNWT, there would also be a relationship between ADG and INWT.

FNWT could affect the interpretation of ADG in one of two ways. The first possibility is that the rate of growth was increasing over the range of 75 to 105 kg (the period in which test termination occurred) and thus ADG measured at 75 kg, say, would not be comparable to that measured at a heavier weight. However, this explanation is not supported in the literature. A review by Robison (1974) concluded that growth was essentially linear within normal slaughter weight ranges. Similarly, Standal (1977) reported linear growth in boars over the weight range 72 to 123 kg while McCampbell and Baird (1961) and Neely et al. (1979) reported ADG on test tended to decrease after about 75 kg.

The second possibility, then, is that rate of growth was constant over the 7[illegible] 105 kg range, but was greater during this period than that achieved during the early portions of the test period. This would result in the lower ADG in the early stages of the growth period constituting a greater proportion of the overall ADG in boars which were terminated light versus those terminated heavy. This hypothsesis is supported by Vangen and Robison (1977) who reported that growth in gilts and boars was lower at the start of test at 22 kg in a Norwegian test station and increased until 40 kg after which time it was essentially linear. Robison (1962) reported a significant quadratic term of weight on age when growth was measured from 14 kg to 84 kg, with growth increasing over this range, although the weight at which growth became linear, if indeed it did, was not reported. However, experiments which have actually calculated ADG at various weights have reported that estimates of ADG on test were similar for pigs carried to heavier weights (Wallace et al. 1959; McCampbell and Baird 1961; Braude et al. 1963; Buck 1963; Skitsko and Bowland 1970; Neely et al. 1979).

If, however, the calculation of ADG was related to the weight at which the boars were taken off test, then FC would be expected to be affected in the same way. Hines et al. (1976) (in Krider et al. 1982) reported that FC ratios (feed/gain) increased when FC was calculated from 34.1 kg to 90.9, 104.5, 118.2 and 131.8 kg, respectively. Similarly, Moen and Standal (1971) concluded from a review of the literature that increasing live weight over a range of 75 to 125 kg was accompanied by decreasing efficiency of feed utilization. Thus one might expect boars which terminated test at higher weights would exhibit higher FC. This, however, was not observed in the present study and, in fact, the opposite occurred. Therefore, there is reason to doubt that the observed relationship between INWT and performance (ADG, FC) resulted from any bias inflicted by differential terminal weights of the various INWT classes.

An alternate means by which the observed relationship between INWT and performance could arise is from the role which INWT plays in determining the length of time which boars spend in the "warm-up", or pretest, period prior to commencing test. The observed relationship between PGTH and PADG would support the hypothesis that there was a certain amount of "equalization", or compensatory gain, exhibited by boars with relatively low rates of growth at submission. Low PGTH values could be produced by "holding back" boars prior to submission and, as weight is the principal criteria for admission to the stations, it is reasonable to assume that boars in the upper weight range would be more likely to have been "held back" than those at lower weights. Furthermore, heavy boars at submission would exhibit any compensatory gain in the early portions of the test period as they would be denied a "warm-up" period by virtue of their heavy weights. Although these data do not permit estimation of genetic and environmental effects and this hypothesis, therefore, cannot be verified, the observed trend in PADG relative to PGTH is sufficient grounds to recommend that all boars entering the test station be provided a standardized period for "warm-up".

A general lack of relationship between the performance traits and WTVR, GRVR and WTDV would tend to indicate that test performance, on either a pen or an individual basis, was not substantially affected by differences between penmates in weight or growth rate at the time of submission to the test stations. However, there was some indication that the heavier boar of a pair at delivery subsequently exhibited superior growth on test.

It did not appear that the distance of breeders from the test stations had substantial effects on the weight [illegible] which boars were delivered. Therefore, there was no indication [illegible] breeders close to the stations attempted to exploit any advantage [illegible] an increase [illegible] delivery weight might have had by delivering boars at heavier weights.

The relatively constant ranking of breeders in the LONT subclass in regards to PGTH is probably indicative of relatively constant environments in these herds with the environments most conducive to PGTH remaining as such over all years. The large amount of variation of INWT from year to year probably indicated a lack of any deliberate effort on the part of the breeders to consistently deliver boars at either extremely heavy or extremely light weights.

Table V-1. Numbers of observations in each station-breed subclass

SUBCLASS	OBSERVATIONS
YONT	604
LONT	566
YLED	728

Table V-2. Class means of the delivery variables (INWT, PGTH, GRVR, WTVR)

CLASS		INWT (kg)			PGTH (kg/day)			GRVR (kg/day)			WTVR (kg)		
		YONT	LONT	YLED	YONT	LONT	YLED	YONT	LONT	YLED	YONT	LONT	YLED
1	n	20	35	69	16	23	43	78	92	67	125	128	142
	mean	20.5	20.5	19.5	0.27	0.28	0.26	0.004	0.004	0.002	0.5	0.4	0.6
2	n	31	35	69	31	48	47	70	49	90	70	59	81
	mean	21.9	22.0	22.1	0.30	0.31	0.30	0.014	0.015	0.014	1.5	1.6	1.7
3	n	80	90	70	74	56	87	50	47	64	41	44	54
	mean	24.1	24.1	24.1	0.33	0.34	0.33	0.024	0.025	0.026	2.5	2.5	2.6
4	n	64	54	49	75	71	90	33	34	47	27	19	32
	mean	26.1	26.1	26.1	0.36	0.37	0.36	0.035	0.035	0.035	3.4	3.4	3.5
5	n	63	40	58	69	49	58	25	23	25	26	23	29
	mean	28.0	27.9	27.9	0.38	0.40	0.38	0.045	0.045	0.045	4.6	4.5	4.5
6	n	44	29	49	37	36	39	46	38	71	13	10	26
	mean	29.8	30.2	30.2	0.42	0.44	0.45	0.068	0.073	0.072	6.5	7.1	6.4

Table V-3. Criteria for coding breeders into DIST classes according to distance (km) from the test station

	YONT		YLED	
CLASS	DISTANCE	NO. OF BREEDERS	DISTANCE	NO. OF BREEDERS
1	1-19	9	1-49	4
2	20-39	11	50-99	5
3	40-59	6	100-199	16
4	60-79	16	200+	9
5	80-99	2		
6	100-199	20		
7	200+	8		

Table V-4. Regression coefficients and the R^2 values of the performance traits on INWT

PERFORMANCE TRAIT	STATION-BREED SUBCLASS	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
ADG	YONT	0.0038 *	0.0017	1.75
	LONT	0.0012	0.0015	0.23
	YLED	0.0039 **	0.0011	3.40
FC	YONT	-0.0093 **	0.0027	3.79
	LONT	-0.0019	0.0034	0.11
	YLED	-0.0055 **	0.0019	2.36
ABF	YONT	-0.0130	0.0340	0.05
	LONT	-0.0210	0.0371	0.03
	YLED	-0.0192	0.0306	0.11
INDEX	YONT	1.104 **	0.332	3.78
	LONT	0.303	0.402	0.26
	YLED	0.950 **	0.326	3.28

* $P<0.05$
** $P<0.01$

Table V-5. Regression coefficients and the R^2 values of the performance traits on PGTH

PERFORMANCE TRAIT	STATION-BREED SUBCLASS	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
ADG	YONT	-0.0690	0.1110	0.13
	LONT	-0.0072	0.0904	0.00
	YLED	0.0365	0.0711	0.07
FC	YONT	-0.3527	0.1808	1.25
	LONT	0.1985	0.2506	0.33
	YLED	0.0542	0.1216	0.05
ABF	YONT	-4.938 *	2.237	1.60
	LONT	-1.491	2.272	0.15
	YLED	3.301	1.959	0.78
INDEX	YONT	40.348	22.600	1.12
	LONT	-4.221	24.107	0.01
	YLED	50.396 *	23.775	1.77

* $P<0.05$

Table V-6. Means (with standard errors in parenthesis) of PADG (expressed as deviations from contemporary group ave.) for each PGTH class

PGTH CLASS	n			PADG (kg/day)		
	YONT	LONT	YLED	YONT	LONT	YLED
1	16	20	36	0.100 (0.057)	0.066 (0.036)	0.024 (0.024)
2	26	39	36	0.040 (0.028)	0.019 (0.029)	0.007 (0.019)
3	47	46	59	0.009 (0.018)	0.015 (0.018)	0.012 (0.018)
4	41	50	48	-0.003 (0.018)	-0.003 (0.026)	-0.006 (0.021)
5	35	34	24	-0.023 (0.024)	-0.020 (0.024)	-0.036 (0.030)
6	17	17	9	-0.128 (0.047)	-0.114 (0.056)	-0.073 (0.022)

Table V-7. Regression coefficients and the R^2 values of PADG on PGTH

STATION-BREED SUBCLASS	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
YONT	-1.18 ***	0.26	9.9
LONT	-0.60 **	0.29	2.0
YLED	-0.40 *	0.24	1.3

* $P<0.10$
** $P<0.05$
*** $P<0.01$

Table V-8. Regression coefficients and the R^2 values of ADG on WTDV

STATION-BREED SUBCLASS	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
YONT	0.0033 *	0.0016	0.08
LONT	0.0034 *	0.0015	0.80
YLED	0.0047 **	0.0013	1.87

* $P<0.05$
** $P<0.01$

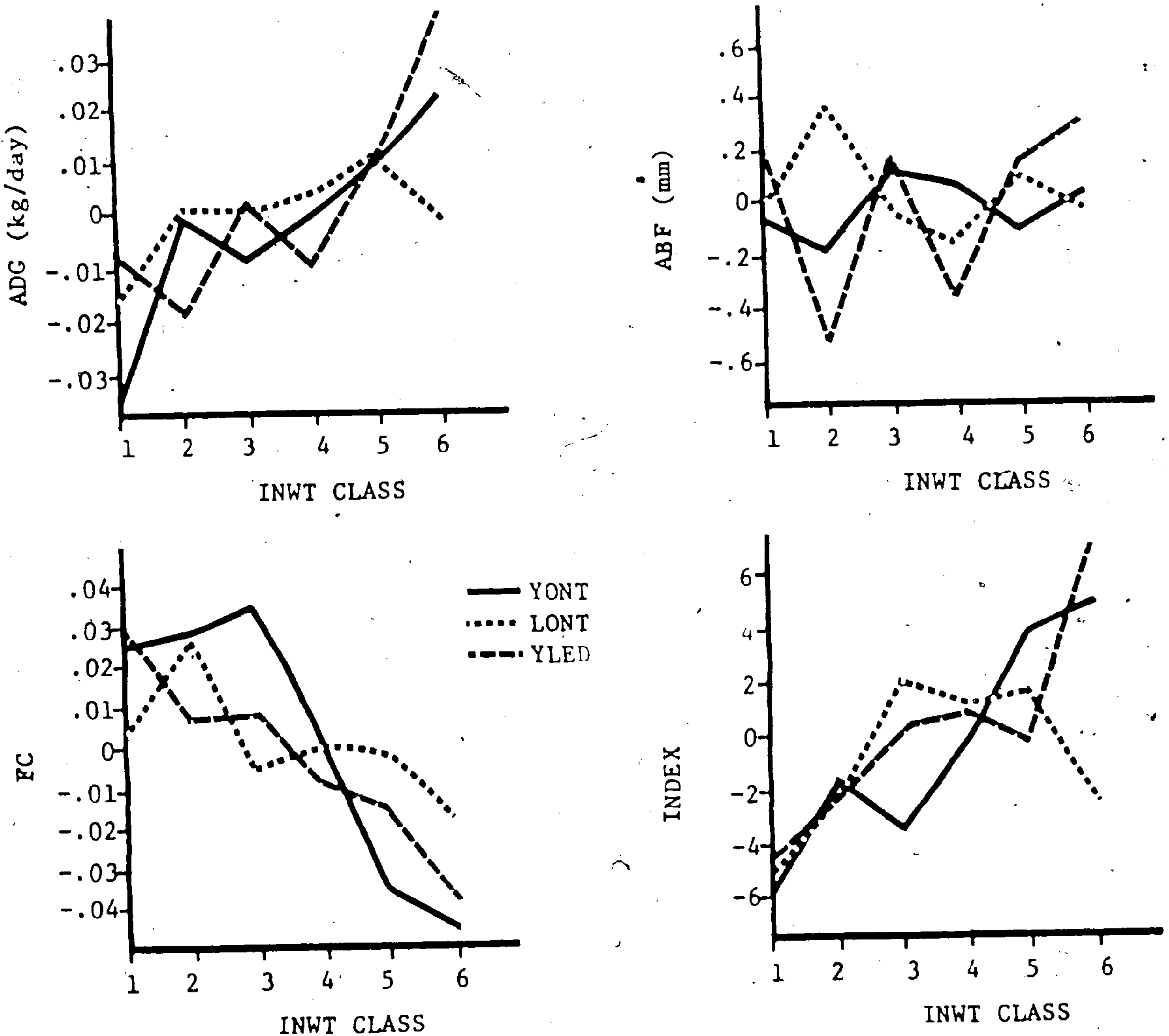

Fig. V-1. Trends in performance traits (expressed as deviations from contemporary group averages) relative to INWT classes.

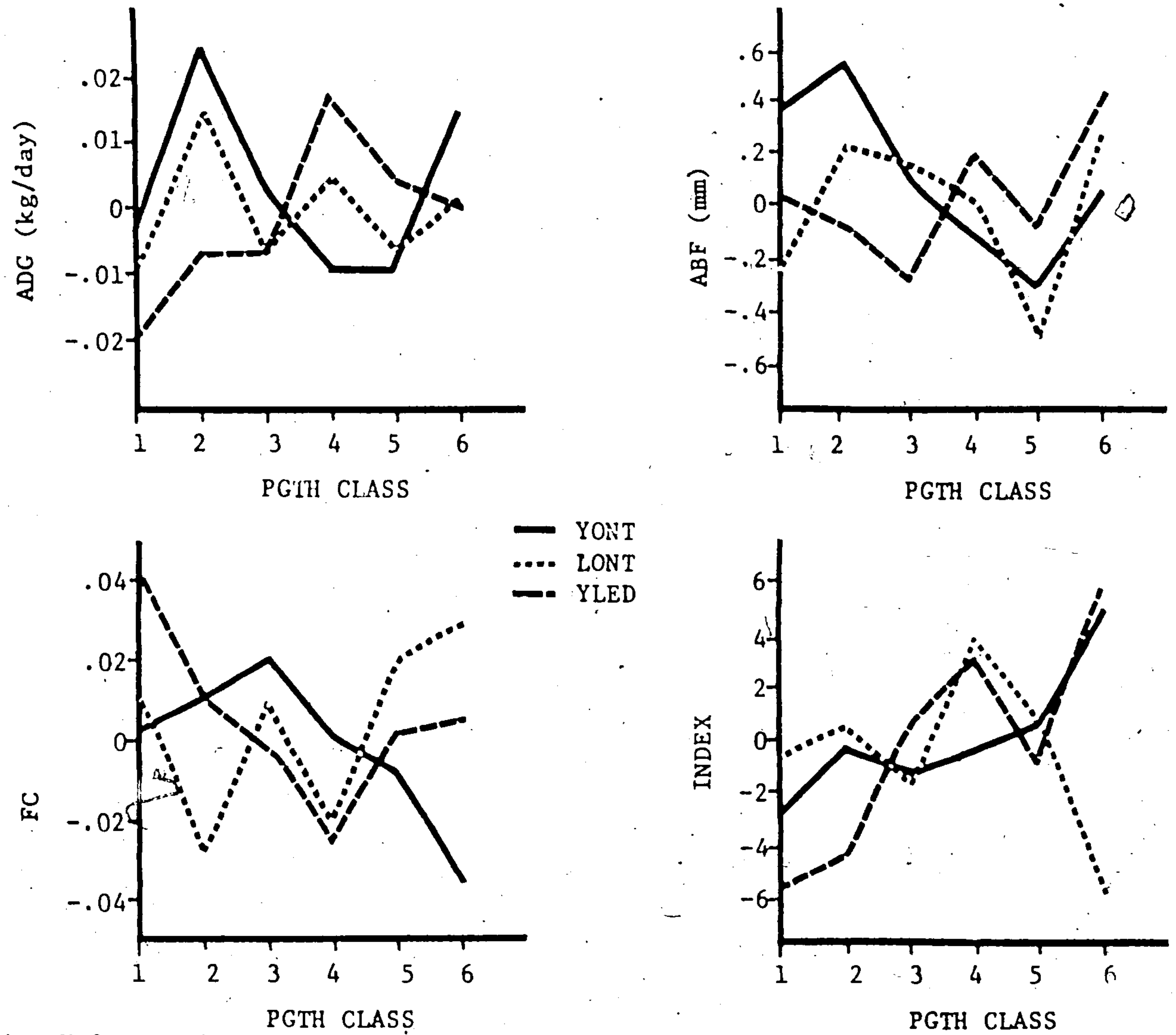

Fig. V-2. Trends in performance traits (expressed as deviations from contemporary group average) relative to PGTH classes.

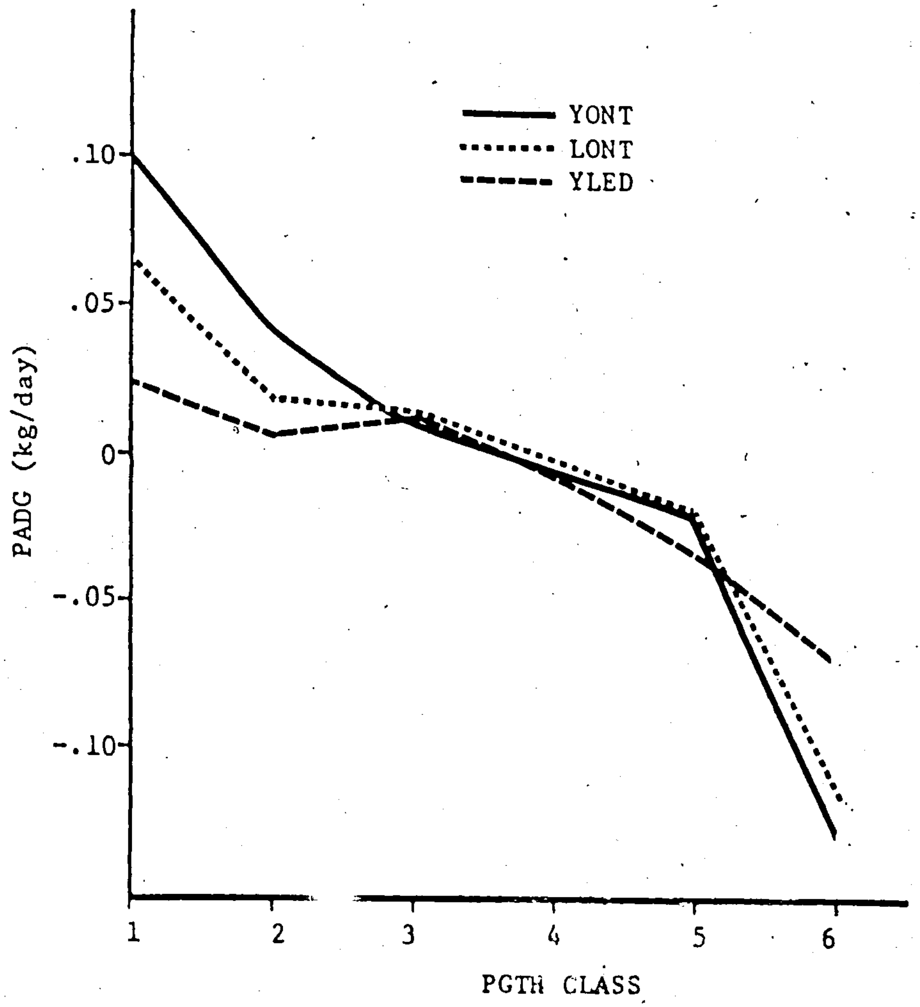

Fig. V-3. Trends in PADG (expressed as deviations from contemporary group average) relative to PGTH classes.

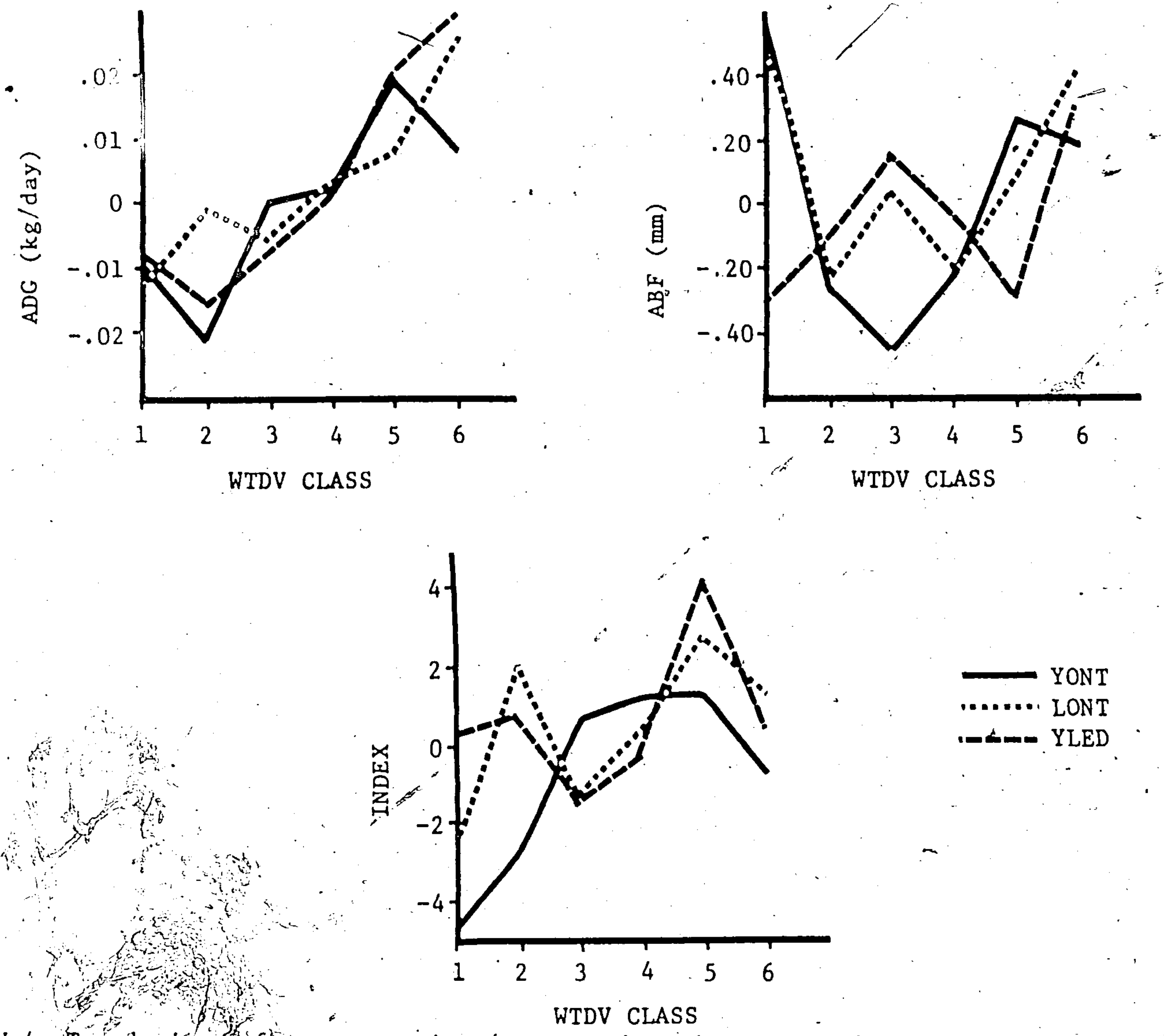

Fig. V-4. Trends in performance traits (expressed as deviations from contemporary group average) relative to WTDV classes.

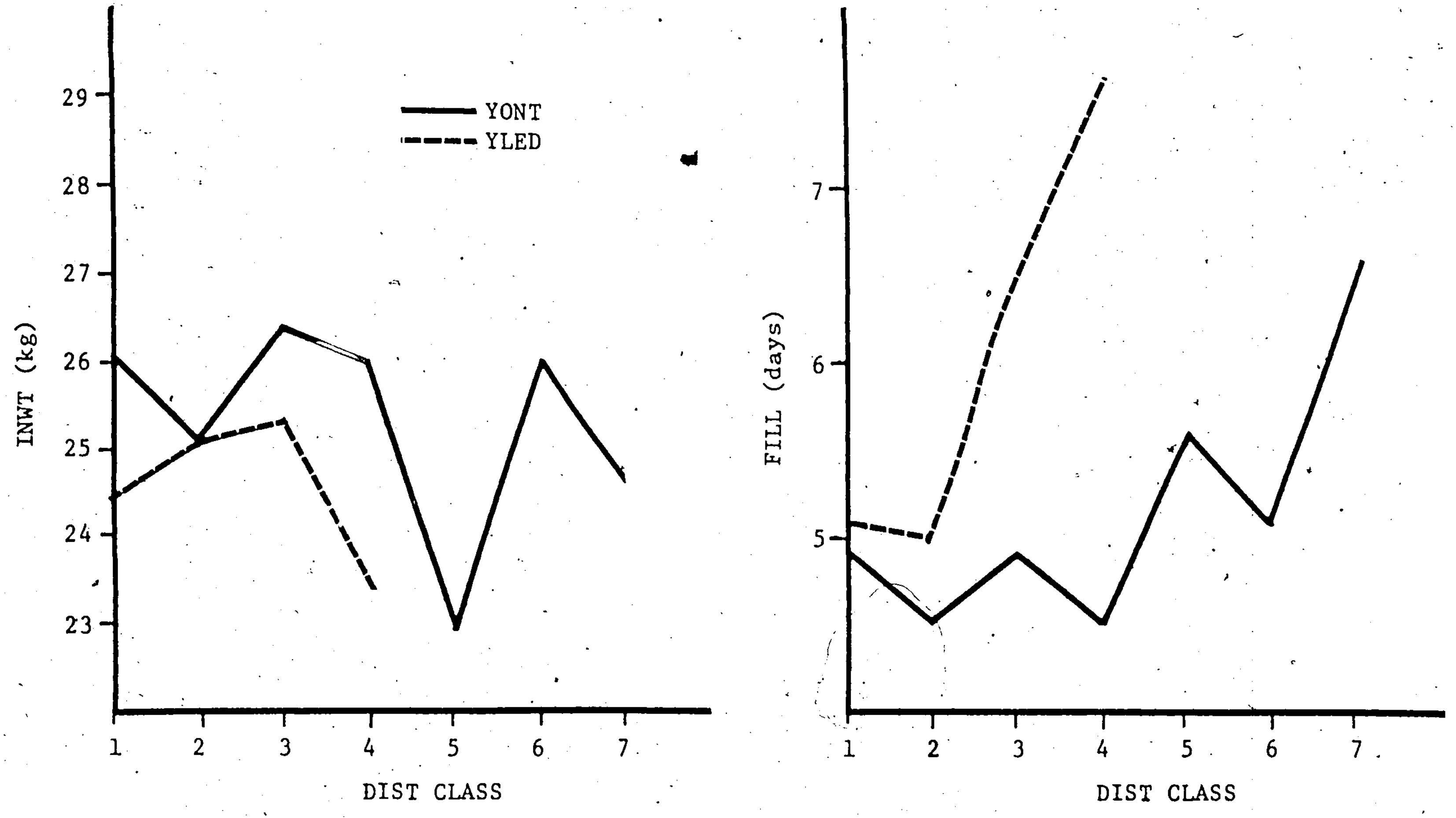

Fig. V-5. Trends in INWT and FILL relative to DIST classes.

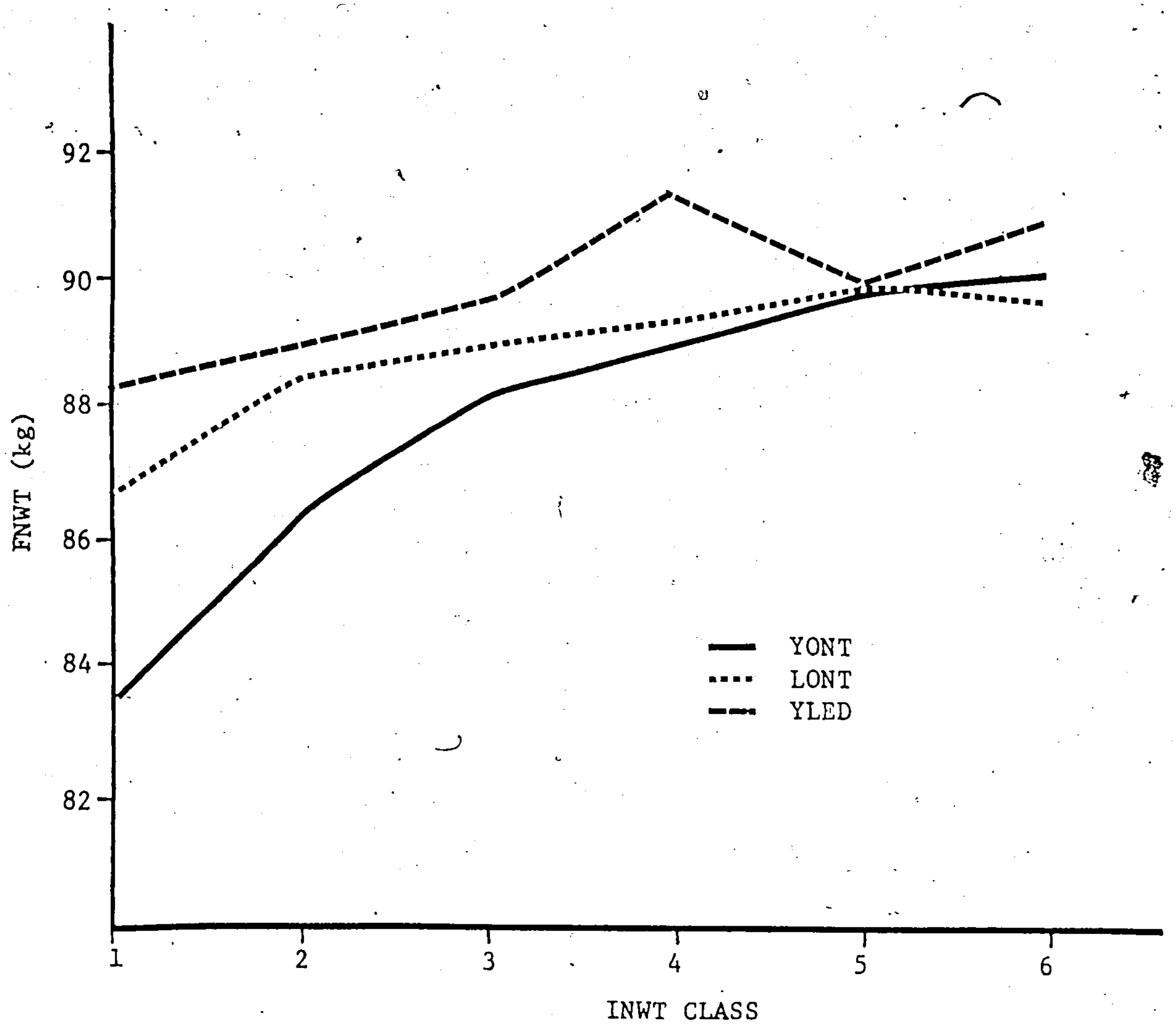

Fig. V-6. Trends in FNWT relative to INWT classes.

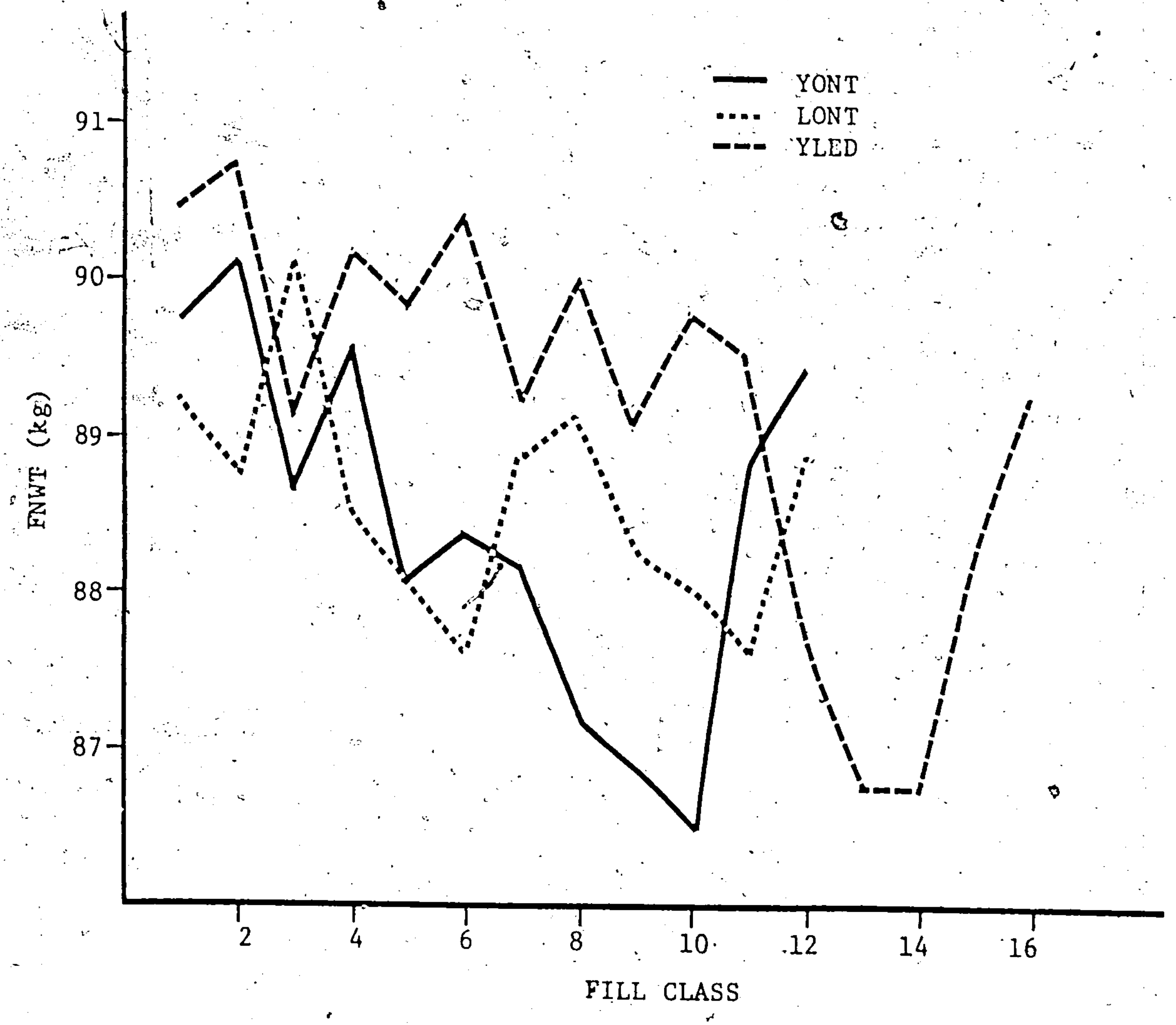

Fig. V-7. Trends in FNWT relative to FILL classes.

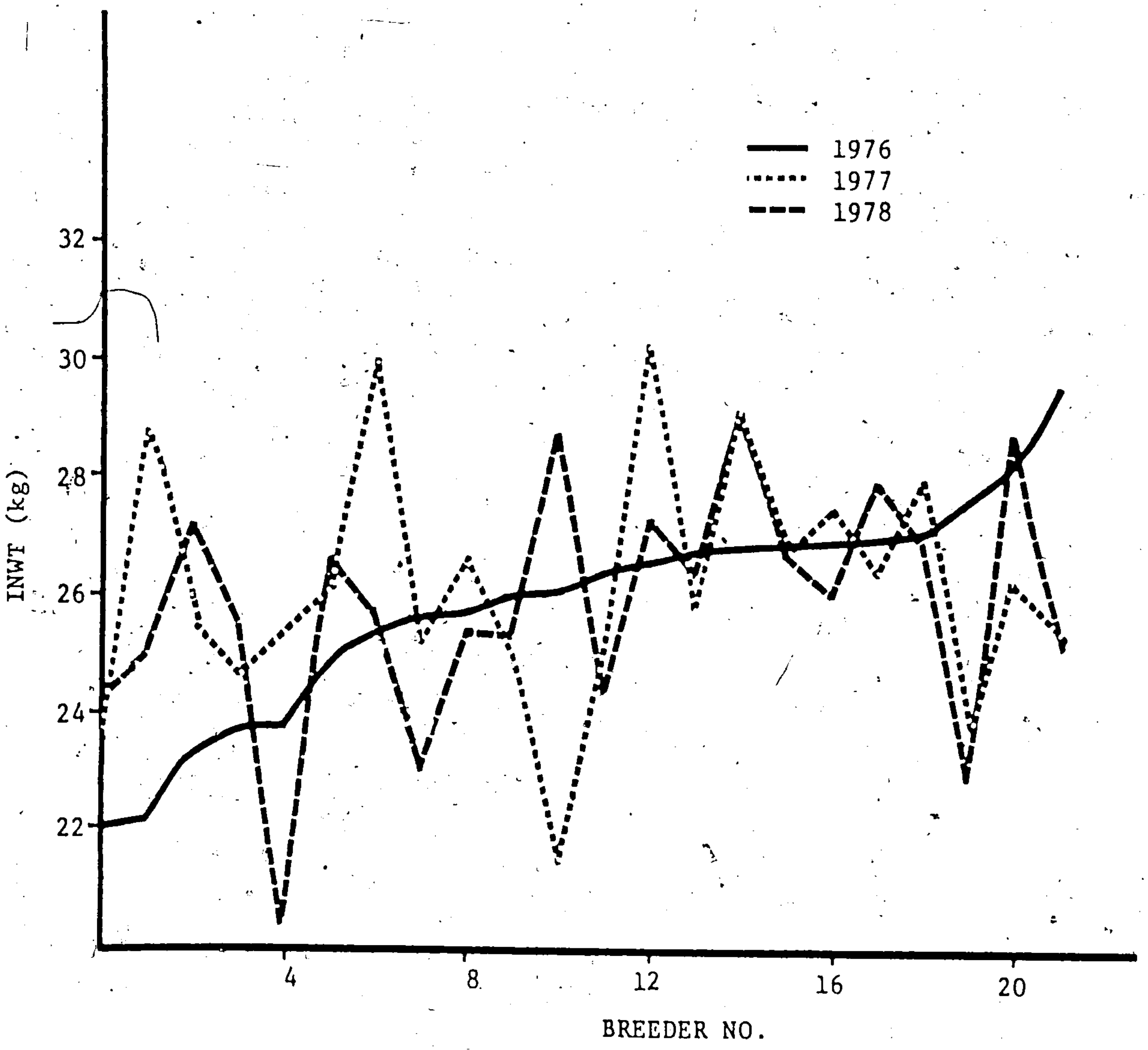

Fig. V-8. Mean INWT of breeders in the YONT subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

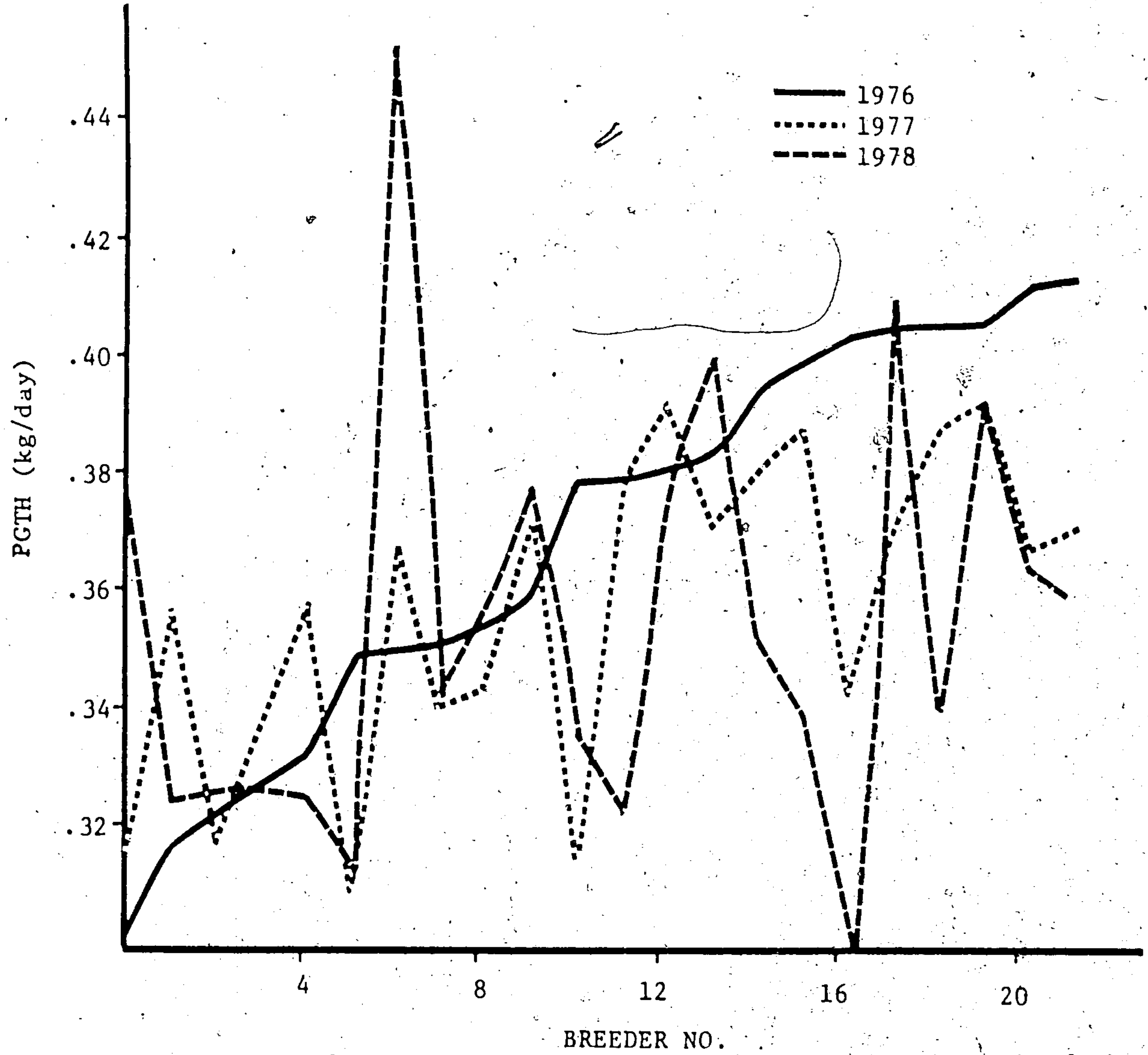

Fig. V-9. Mean PGTH of breeders in the YONT subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

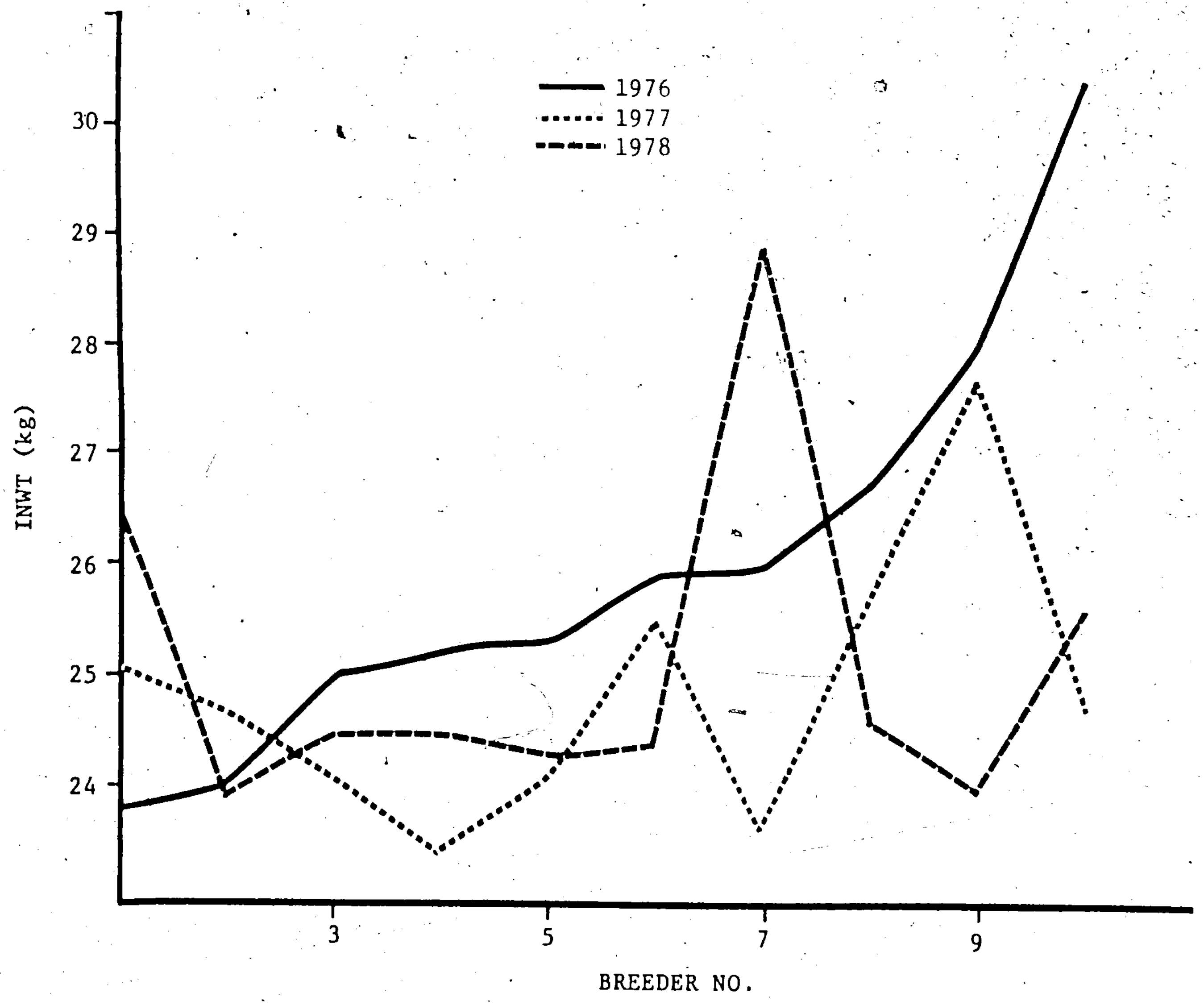

Fig. V-10. Mean INWT of breeders in the LONT subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

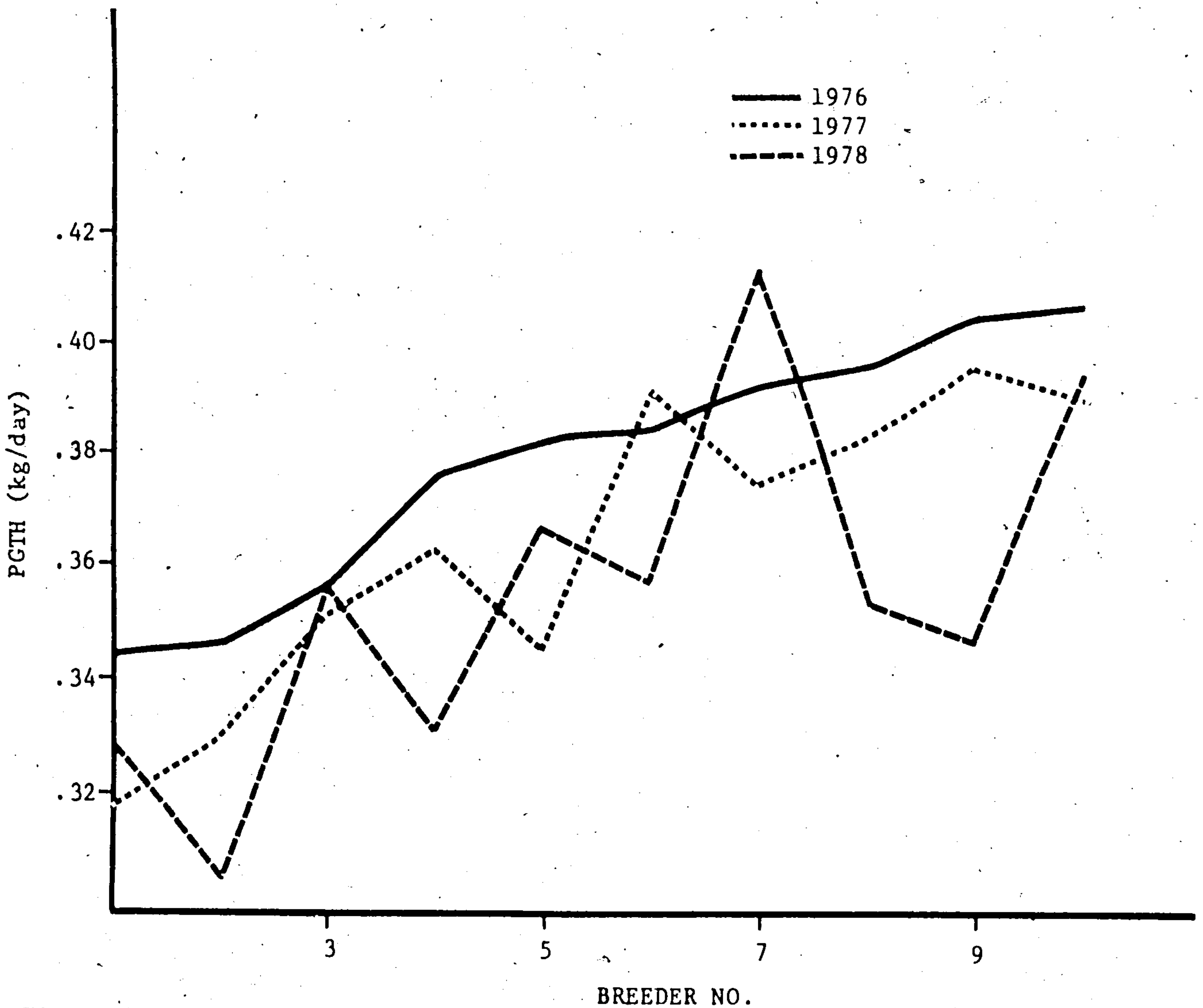

Fig. V-11. Mean PGTH of breeders in the LONT subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

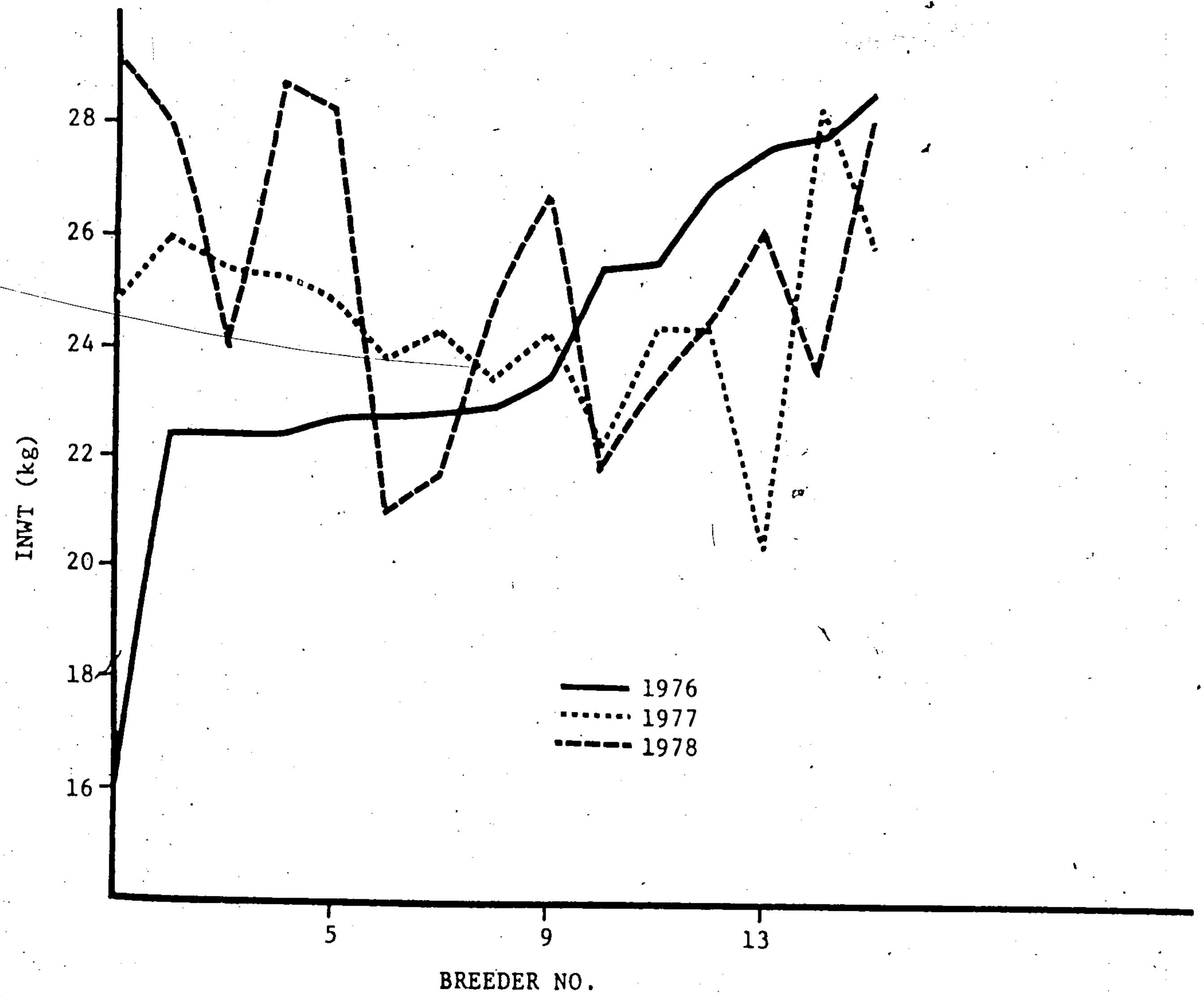

Fig. V-12. Mean INWT of breeders in the YLED subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

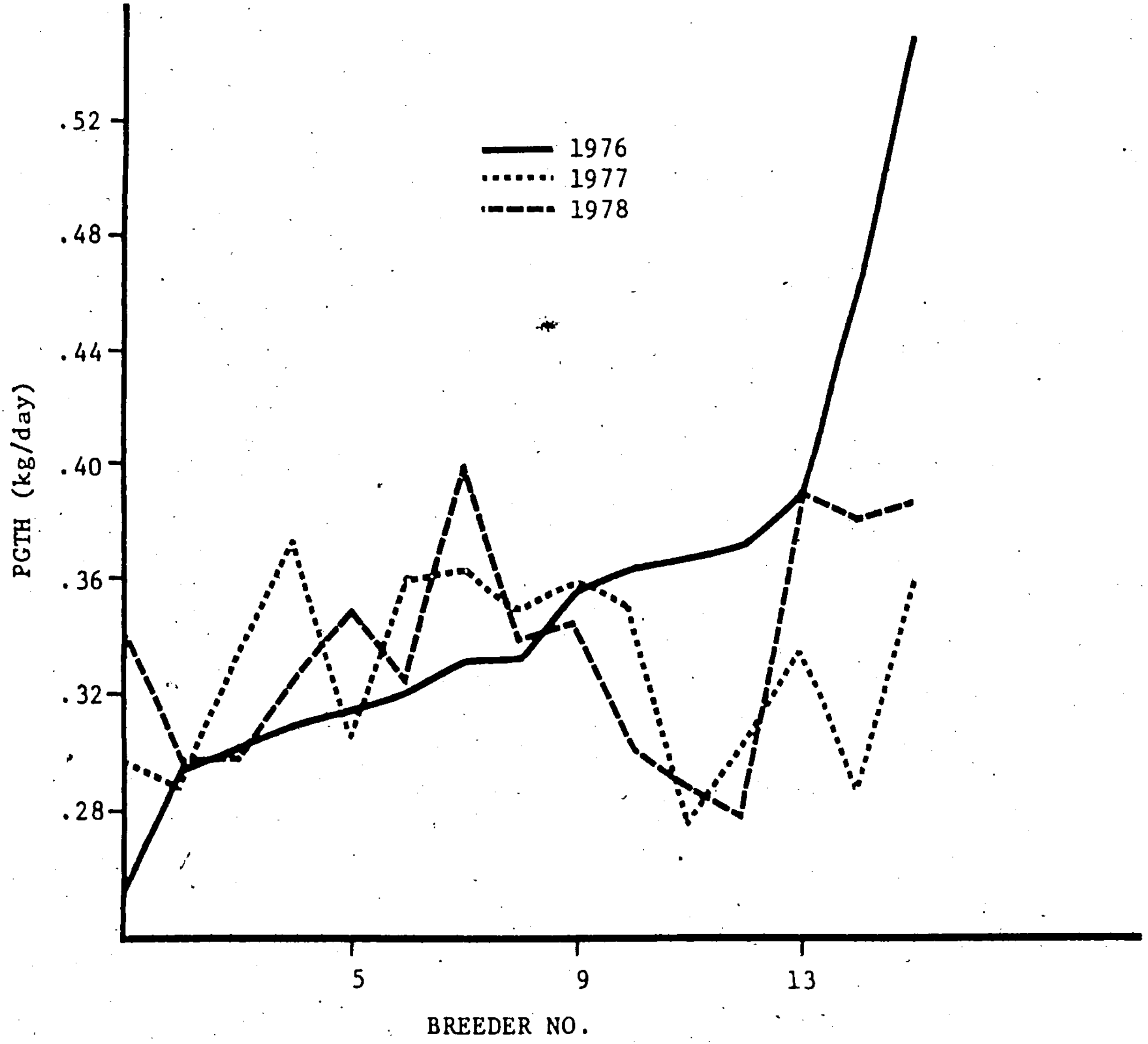

Fig. V-13. Mean PGTH of breeders in the YLED subclass testing in each of three years (1976, 1977, 1978) relative to the ranking based on 1976 values.

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VI. BACKFAT DEPOSITION AND ADJUSTMENT OF BACKFAT FOR LIVEWEIGHT AT END OF TEST IN ROP PERFORMANCE TESTED BOARS

A. INTRODUCTION

The advent in the 1950's of such techniques as ultrasonics in Europe (Jonsson 1975) and the live backfat probe technique of Hazel and Kline (1952) in North America heralded a new era in pig testing. These techniques made possible the measurement of backfat depth on the live animal and estimates of this trait could be obtained directly from potential breeding stock rather than relying on progeny or sib performance. Since that time the measurement of backfat depth has become a common element of swine performance testing programs throughout the world. Backfat measurements are made at the termination of test which is usually defined as being at, or close to, 90 kg (e.g. Jonsson and King 1962; Quijandria et al. 1970; Moen and Standal 1971; Neville et al. 1976; McPhee 1979; Mitchell et al. 1982; Sather 1983) to conform with the market requirements of slaughter pigs.

The target terminal weight is rarely achieved exactly. The deviations are greatest in group fed pigs where testing policy requires that all animals be terminated at a standard average pen weight rather than at a standard individual pig weight. Thus to provide the weight standardization required for genetic comparisons of backfat among tested animals it is necessary to invoke statistical adjustments to the standard terminal weight. Each testing program employs its own adjustment procedure but all are similar in format to that used in Canada. The Canadian Record of Performance (ROP) swine testing program currently uses the following backfat adjustment:

$$ABF = (90/FNWT) \times (TBF/4)$$

where:

ABF = average adjusted backfat (mm) to 90 kg
FNWT = weight at completion of test (kg)
TBF = sum of 4 ultrasonic backfat measurements at test completion (mm)

This procedure assumes a linear rate of backfat deposition from birth (at zero weight and zero backfat) to the final weight observed. Thus the assumed regression line of backfat on WT passes through two points; the intercept of zero and the point defined by actual weight and actual backfat at test termination. The regression coefficient (b_A) of this line would be:

$$b_A = BF / FNWT$$

where:

BF = average backfat depth at test termination (TBF/4)
FNWT = weight at test termination

ABF values would be obtained from the backfat values on this line at 90 kg.

While the rate of backfat deposition would not be expected to be linear throughout the life of the pig there is considerable evidence to support the assumption of linearity through the growing period. Thus Hetzer et al. (1956), Noffsinger et al. (1959), Robison (1962), Quijandria and Robison (1971), Standal (1977) and Jesse et al. (1983), in experiments involving fat measurements at regular intervals through the period of growth, found significant linear regressions with evidence of a nonlinear component in only one case (Quijandria and Robison 1971). However, as a quadratic component occurred in only one subclass in this latter study, these authors concluded that the relationship between backfat and liveweight was essentially a linear one. The above studies covered weight ranges of 68 to 102 kg, 45 to 90 kg, 43 to 84 kg, 57 to 82 kg, 63 to 123 kg and 104 to 131 kg, respectively, and resulted in regression coefficients ranging from 0.090 to 0.484 mm/kg liveweight (Table VI-1). The variation in the regression coefficients as reported in Table VI-1 appear to be a result of both sex and line (or nutrition/management) effects. Thus while boars and gilts had lower rates of backfat deposition compared to barrows, the study involving the leanest pigs (Standal 1977) also reported the lowest coefficients. Only two of the studies reported growth rates, but from this limited information there was no indication of a relationship between ADG and the rate of backfat deposition. Standal (1973), using "on-the-farm" data which provided only final weight and backfat information, reported regression coefficients of 0.164 and 0.121 mm/kg in gilts and boars respectively.

While these data demonstrate that regression coefficients are specific to individual populations, they also validate the assumption (i.e. linearity of the rate of backfat deposition) basic to the Canadian ROP adjustment procedure. However, it is self-evident that the accuracy of this procedure is inversely related with the weight deviation over which the adjustment is applied. The objective of the present study was to examine the possibility that the divergence in final weights associated with penmate differences in growth rate might result in over or under estimation of backfat.

B. MATERIALS AND METHODS

The data set for this study comprised the records of all boars of the three principal breeds which successfully completed test (3735 Yorkshire boars, 1869 Landrace boars and 921 Duroc boars). The data for each boar included final weight in kg (FNWT) and average backfat in mm (BF) with individual boars in a pen usually deviating above and below this weight (i.e. pen mates usually differed in FNWT). This type of data was catagorized as "cross-sectional" by Fitzhugh (1976).

Data for each breed were crossclassified into quadrants according to BF and FNWT. FNWT was coded as being above or below 90 kg and BF was coded as being above or below the breed average. The purpose of classifying the data in this manner was to examine whether differential backfat deposition rates existed between the quadrants. The quadrants could be referred to generally as containing the following groups of boars (Table VI-2):

1 = light, fat
2 = heavy, fat
3 = light, lean
4 = heavy, lean

Crossclassifying the data in this manner also facilitated the examination of the effects of growth rate on backfat deposition as the quadrants differed significantly ($P<0.05$) in mean ADG (Table VI-3).

Rates of backfat deposition within each quadrant, and pooled over quadrants, were determined by regressing BF on FNWT, breeds separate, using the model:

$$Y_{ij} = u + C_i + b_1 FNWT + e_{ij}$$

where:

Y_{ij} = BF of the j^{th} individual within the i^{th} contemporary group

u = overall mean

C_i = effect of the i^{th} contemporary group defined by herd-station-year-section-fill

b_1 = linear regression coefficient of BF on FNWT for quadrants separate (b_Q) or pooled over quadrants

e_{ij} = random error term

The C_i effect, represented by 968 Yorkshire, 475 Landrace and 286 Duroc contemporary groups, was absorbed prior to the estimation of regression coefficients after the manner employed by Standal (1977) for absorption of herd effects. All analyses were also performed with inclusion of a quadratic effect, the model in this case being:

$$Y_{ij} = u + C_i + b_1 FNWT + b_2 FNWT^2 + e_{ij}$$

where:

b_2 = the regression coefficient of BF on $FNWT^2$

The regression coefficient assumed by the ROP adjustment procedure (i.e. b_A = BF/FNWT) was calculated for each boar. The regression coefficient of BF on FNWT derived from the within quadrant analyses (b_Q) was then subtracted from this value to obtain the deviation between the two coefficients. These deviations were averaged by quadrant to determine to what extent the regression on which the ROP adjustments were made differed from those derived from the data. These average deviations were used to predict the differences in adjusted average backfat values which would result from using the ROP adjustment procedure rather than a procedure employing the regression coefficients derived from the data. That is:

$$D_{ABF} = ABF - ABF'$$

where:

D_{ABF} = difference in adjusted average backfat values

ABF = adjusted average backfat derived using the ROP adjustment

ABF' = adjusted average backfat derived using b_Q

(i.e. $ABF' = BF + b_Q[90-FNWT]$)

The differences in index values which would result from using the two different ABF values (i.e. ABF versus ABF') were calculated by applying D_{ABF} to the 2 trait phenotypic index in use presently by the ROP swine program.

Thus, assuming that the ADG parameters and mean ABF remained constant in the index, the change in the index value (D_{INDEX}) resulting from differences in the ABF measurements would be:

$$D_{INDEX} = 17.68\ (D_{ABF}\ /\ SD'_{ABF})$$

where:

D_{INDEX} = difference in the index values derived using ABF versus ABF'

D_{ABF} = ABF-ABF'

SD_{ABF} = standard deviation in ABF of the contemporary group used in construction of the index

SD_{ABF} for each of the three breeds, based on pooled within breed-year-station-section-fill subclass estimates, were 2.78, 2.69 and 2.33 mm for Yorkshires, Landrace and Durocs, respectively. D_{ABF} and D_{INDEX} were compared at the extreme ends of the FNWT range (75 versus 105 kg).

C. RESULTS

The regression of BF on FNWT, quadrants pooled, indicated that the rate of backfat deposition was not significantly different among breeds and ranged from 0.188 to 0.216 mm/kg (Table VI-4). However, the coefficients derived from within quadrant analysis (Table VI-5) produced values consistently less than those from the pooled analysis. These values were not significantly different (P>0.05) among any of the quadrants in any of the breeds although the differences approached significance (P=0.11) in the Yorkshires. There did appear to be a tendency for quadrant 4 to exhibit consistently lower regression coefficients. This suggested that the heavy, lean boars deposited BF at a slower rate relative to liveweight than the other quadrants. However, the converse was not always the case as in the Landrace breed quadrant 1 boars (light, fat) exhibited a lower coefficient than quadrant 4 boars. Although the regressions were significant in all cases, the amount of variation explained by the regression of BF on FNWT was relatively small as evinced by the low R^2 values.

In none of the regression analyses performed in this study did a model including a quadratic term indicate that regressions deviated significantly from linearity. It must be remembered, though, that the regressions obtained apply only to the range in final weights observed in this study. Extrapolations beyond the range of these data cannot be made and thus linearity beyond this range cannot be assumed.

While the regression coefficients were not significantly different among quadrants and there were no consistent trends apparent within each breed, the regression coefficients assumed by the adjustment procedure exhibited a consistent downward trend from quadrant 1 to 4

(Table VI-6). This resulted from the nature of the adjustment procedure as all boars were regressed through zero resulting in lighter, fatter pigs being assigned greater rates of backfat deposition than heavier, leaner pigs.

The mean deviations between the two regression coefficients (i.e. $b_A - b_Q$) were large and positive in each quadrant, deviating from zero in every case by at least 8 times the standard error (Table VI-7). The implications of these findings are that, on average, the regression lines along which adjusted backfat values to 90 kg were obtained were greater in slope than those regression lines derived from the data on a within quadrant basis. As boars in quadrants 1 and 3 were forward adjusted and those in quadrants 2 and 4 were backward adjusted to 90 kg, this would indicate that boars completing test less than 90 kg would have backfat measurements adjusted to values which were too high (i.e. overadjustment) while those completing test at weights greater than 90 ~~kg~~ would have BF adjusted to values which were too low (i.e. underadjustment). This conclusion is supported by the examination of the regressions of adjusted average backfat (ABF) on FNWT (Table VI-8). All regression coefficients within quadrant (breeds separate) were negative though only three coefficients in the Yorkshire breed and two in the Landrace were significant ($P<0.05$).

The differences between adjusted backfat values which would be arrived at by using the two different regression coefficients (i.e. b_A vs. b_Q) are, of course, directly related to the magnitude of the deviation of FNWT from 90 kg (Fig. VI-1). They are minor when the deviation is small but reach substantial values for the extremes in weight deviations (e.g. a maximum of 2.14 mm in quadrant 1 for the

Landrace breed, Fig. VI-1). Thus at these extremes in weight deviations, the ROP adjustment procedure can lead to errors in index calculations of up to 14 index points.

D. DISCUSSION

The results of the analyses performed in the present study indicated that the adjustment procedures presently in use by the ROP swine program bias adjusted backfat values in favour of boars terminating test at weights greater than 90 kg. A similar conclusion was reached by Kennedy (1984) based on preliminary results.

While use of the ROP adjustment procedure implies that boars completing test at lower levels of BF and higher FNWT have lower rates of backfat deposition than those completing test at higher BF levels and lower FNWT, there was no indication of this phenomenon in the present data. Admittedly, though, the data available were less than ideal for this type of analysis. However, classifying the data into heavy and light groups as was done in this study would be expected to remove some of the confounding of final weight and growth rate, which is inherent in this kind of data (Standal and Moen 1971). This would, in part, explain the lower regression coefficients derived on a within quadrant basis as compared to those from a pooled over quadrant analysis. This observation points out the danger involved in trying to obtain adjustment factors from data of this type as adjustment for liveweight becomes an adjustment for ADG as well. Only in populations where the genetic correlation between backfat and ADG is zero would adjustment factors derived from this type of data be free of the effects of ADG (Standal 1973). However, reports in the literature of substantial positive correlations between these two traits on ad lib. feeding (e.g. Robison and Berruecos 1973; Fredeen et al. 1980; Rothschild et al. 1981) indicate that this assumption cannot be made.

To obtain accurate estimates of backfat deposition rates the boars would have to be sequentially weighed and probed. Regression coefficients thus obtained would be on a within pig basis and would be free of any genetic covariance between backfat and liveweight (Standal 1973).

The regression coefficients which were obtained in this study, however, did indicate that the actual rates of backfat deposition may have been substantially less than those implied by the adjustment procedure. Thus, a nongenetic advantage in terms of adjusted backfat values, and resulting index values, would be bestowed upon boars completing test at a final weight greater than 90 kg for whatever reason. This advantage would be greater at higher terminal weights. For this reason, those boars in pens with a slow growing pen mate (with its resultant lowering of the average pen weight) would be at an advantage compared to those in pens with more evenly matched growth rates. Similarly, pens entered at light weights and late in the fill period would run a greater chance of being terminated early (less than 90 kg) to facilitate clearing out the fill and would have their backfat values overadjusted; the severity of the overadjustment depending on the deviation from the 90 kg target weight. The bias in the adjustment procedure could, therefore, change the ranking of the boars in a contemporary group for purely non-genetic reasons.

The "best" solution to the problem of statistical adjustments is, of course, the avoidance of such whenever possible. Although this would not be feasible in all cases. Such an approach is not outside the boundaries of practicality as [illegible] to the collection of backfat data at swine ROP test stations [illegible] fat depth at 90 kg could be obtained directly by probing [illegible] close as is practically possible, to this weight. This [illegible] labour costs by necessitating an increase in weighing [illegible] but would allow the pig to provide backfat values at a standard weight rather than relying on statistics to achieve this end. The ability to collect feed conversion data on penmates would not have to be sacrificed as boars could remain on test after probing until the lightest penmate reached 90 kg.

Table VI-1. Summary of backfat deposition rates (and associated pertinent information) as reported in the literature

	REFERENCE				
	Standal 1977	Quijandria and Robison 1971	Noffsinger et al. 1959	Hetzer et al. 1956	Jesse et al. 1983
n	116(M) 258(F)	777 (M+F+B)	45(B) 52(F)	45(M) 30(B) 65(F)	360(M)
REGRESSION COEFFICIENT (mm/kg)	0.090(M) 0.120(F)	0.484 (M+F+B)	0.285(B) 0.229(F)	0.246(M) 0.319(B) 0.235(F)	0.240(M)
AVERAGE BACKFAT (mm)	12.8(M) 13.2(F)	29.3 (M+F+B)	40.1 (B+F)	32.5(M) 35.3(B) 35.8(F)	26.1(M)
FINAL WEIGHT (kg)	95.1(M) 87.4(F)	82.1 (M+F+B)	90.9 (B+F)	90.9 (M+B+F)	131.5(M)
SITES OF BACKFAT MEASUREMENT	shoulder midback loin	loin	shoulder midback loin	shoulder midback loin	shoulder midback loin
AVERAGE DAILY GAIN (kg/day)	0.57(M) 0.52(F)	-	0.60 (B+F)	-	-

M = male F = female B = barrow

Table VI-2. Number of observations and means (with standard error in parenthesis) of BF and FNWT for each quadrant by breed

BREED	QUADRANT	n	BF	FNWT
Yorkshire	1	601	18.5 (0.08)	85.8 (0.14)
	2	1050	19.3 (0.08)	95.1 (0.12)
	3	1253	13.5 (0.05)	84.1 (0.11)
	4	831	14.2 (0.05)	94.1 (0.12)
Landrace	1	372	19.0 (0.10)	85.0 (0.21)
	2	518	19.8 (0.11)	94.6 (0.16)
	3	599	14.0 (0.07)	84.0 (0.17)
	4	380	14.6 (0.07)	93.7 (0.15)
Duroc	1	160	17.9 (0.13)	85.8 (0.27)
	2	286	18.6 (0.13)	95.2 (0.25)
	3	274	13.4 (0.10)	84.2 (0.25)
	4	201	13.9 (0.09)	93.9 (0.23)

Table VI-3. Means (with standard errors in parenthesis) of ADG by quadrant and breed

BREED	QUADRANT	ADG
Yorkshire	1	0.86 (0.004) b[+]
	2	0.94 (0.003) d
	3	0.79 (0.003) a
	4	0.89 (0.003) c
Landrace	1	0.86 (0.005) b
	2	0.92 (0.004) d
	3	0.80 (0.004) a
	4	0.88 (0.004) c
Duroc	1	0.88 (0.007) b
	2	0.95 (0.005) d
	3	0.81 (0.005) a
	4	0.89 (0.006) c

[+] means within the same breed with different letters are significantly different ($P<0.05$)

Table VI-4. Regression coefficients pooled over quadrants of BF on FNWT and the R^2 values

BREED	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
Yorkshire	0.211 **	0.007	11.2
Landrace	0.216 **	0.010	10.7
Duroc	0.188 **	0.011	10.6

** $P<0.01$

Table VI-5. Regression coefficients, within quadrant, of BF on FNWT and the R^2 values

BREED	QUADRANT	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2 (%)
Yorkshire	1	0.122 **	0.036	1.8
	2	0.159 **	0.027	2.4
	3	0.121 **	0.016	2.6
	4	0.072 *	0.022	1.0
Landrace	1	0.081 **	0.036	1.1
	2	0.144 **	0.040	1.7
	3	0.159 **	0.022	4.8
	4	0.089 *	0.032	1.5
Duroc	1	0.170 *	0.073	3.5
	2	0.112 *	0.047	1.3
	3	0.137 **	0.029	4.4
	4	0.089 **	0.033	2.0

* $P<0.05$

** $P<0.01$

Table VI-6. The average adjustment coefficients as derived by the ROP adjustment procedure (within quadrant, breeds separate)

BREED	QUADRANT	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT
Yorkshire	1	0.216	0.001
	2	0.203	0.001
	3	0.161	0.001
	4	0.151	0.001
Landrace	1	0.224	0.001
	2	0.209	0.001
	3	0.167	0.001
	4	0.156	0.001
Duroc	1	0.209	0.002
	2	0.196	0.002
	3	0.160	0.001
	4	0.148	0.001

Table VI-7. Deviations between the two regression coefficients b_A (the coefficient implied by the ROP adjustment procedure) and b_Q (coefficient derived from the data)

	DEVIATION ($b_A - b_Q$)		
QUADRANT	YORKSHIRE	LANDRACE	DUROC
1	0.094 (0.001)	0.143 (0.001)	0.039 (0.002)
2	0.044 (0.001)	0.065 (0.001)	0.084 (0.002)
3	0.040 (0.001)	0.008 (0.001)	0.023 (0.001)
4	0.07[illegible] (0.001)	0.067 (0.001)	0.059 (0.001)

Table VI-8. Regression coefficients, within quadrant, of ABF on FNWT and the R^2 values

BREED	QUADRANT	REGRESSION COEFFICIENT	STANDARD ERROR OF REGRESSION COEFFICIENT	R^2(%)
Yorkshire	1	-0.112 *	0. 38	1.3
	2	-0.041	0. 16	0.2
	3	-0.044 *	0.018	0.3
	4	-0.071 *	0.021	1.0
Landrace	1	-0.168 *	0.039	3.5
	2	-0.060	0.038	0.3
	3	-0.009	0.024	0.0
	4	-0.061 *	0.031	0.8
Duroc	1	-0.050	0.076	0.2
	2	-0.076	0.044	0.6
	3	-0.023	0.032	0.1
	4	-0.050	0.032	0.6

* $P < 0.05$

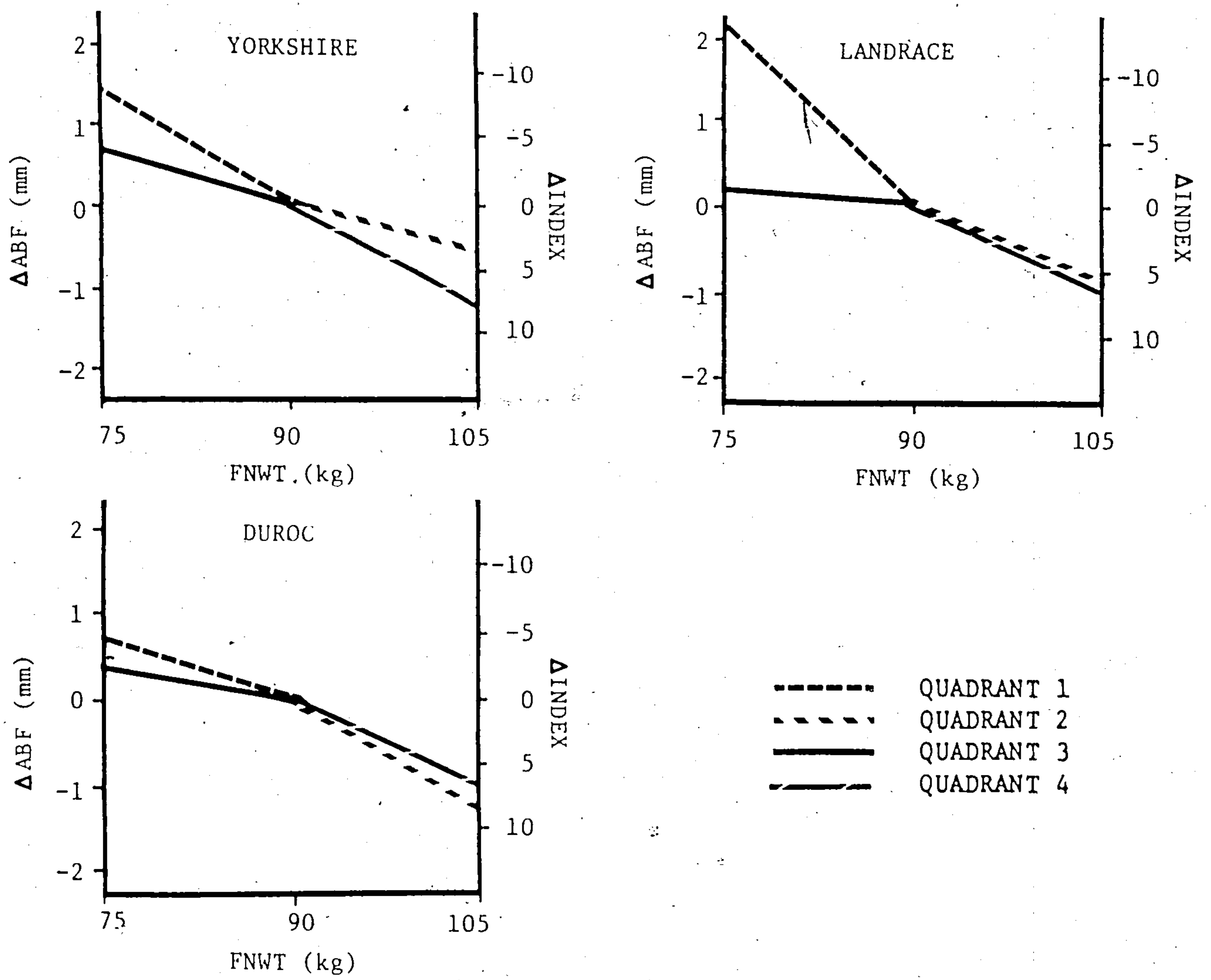

Fig. VI-1. Differences in ABF (ΔABF) and INDEX (ΔINDEX) when BF is adjusted to 90 kg via the ROP adjustment procedure rather than along a regression line derived from ROP data.

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VII. BACKFAT DEPOSITION AND GROWTH PATTERNS FROM 75-105 KG IN ROP STATION TESTED BOARS

A. INTRODUCTION

In order to accurately estimate backfat deposition and growth patterns, sequential age and backfat depths must be obtained on individual pigs over a range of weights. This type of data is not normally available from ROP tested pigs as probing occurs only once (i.e. at the completion of test). A unique opportunity arose in 1972 when a complete fill of boars at the Lacombe, Alberta test station had to be slaughtered due to health concerns. This afforded the chance to conduct sequential probings over a range of weights and to carry these boars to higher terminal weights than would otherwise be possible under the policy of the ROP program.

The objective of this study was to utilize the resulting data to examine patterns of backfat deposition and growth over the normal range of ROP test termination weights (i.e. 75 to 105 kg). This information was used to determine the validity of the present backfat and age adjustment procedures and to test an alternative method of backfat adjustment.

B. MATERIALS AND METHODS

The population for this study comprised 120 boars tested in pens of two as full sib pairs at the Lacombe, Alberta ROP test station in the summer of 1972. The boars were ultrasonically probed and weighed once weekly over a two month period with backfat depth (mm) recorded at the shoulder, midback and loin. Weights at the time of probing varied among the boars over this period from a minimum of 38 kg to a maximum of 144 kg though all boars were not weighed over equivalent ranges. The two principal breeds tested were Yorkshire and Lacombe with 72 and 32 boars, respectively, although there were also representatives of Hampshires, Poland China and Pietrain with 10, 4 and 2 test animals, respectively.

As the policy of the Canadian ROP swine testing program stipulates that boars must complete test within the range of 75 to 105 kg, the data were restricted to those boars which had weights recorded over this range. The weights for each boar included in the restricted data set were those weights between the first weight closest to, but less than 75 kg, and the first weight greater than 103.5 kg. The reason for an upper limit of 103.5 kg rather than 105 kg was to expand the data set to allow inclusion of 4 additional boars which were terminated slightly lighter than 105 kg. In addition, the analyses were restricted to the two principal breeds. The application of these restrictions reduced the data set to 55 boars; 37 Yorkshires and 18 Lacombes. Although this represented a severe reduction of the data set, it was felt that these restrictions were necessary to insure that: (a) backfat deposition and growth data were available over the entire range of the 75 to 105 kg test termination period, and (b) all boars provided data over an equivalent weight range.

Two methods were utilized to adjust average backfat (BF). The first (Method I) was the standard ROP procedure which adjusted BF to 90 kg (i.e. ABF = [90/WT]BF where WT represents liveweight at the time of probing). The second method (Method II) utilized the pooled within pig (across breeds) regression coefficient of BF on WT. In this case the adjusted BF values were obtained by the equation:

$$ABF = BF + b_p(90-WT)$$

where b_p represents the pooled within pig regression coefficient of BF on WT.

To examine the effectiveness of Method II, boars were designated at random within pen to one of two groups. The regression coefficient, b_p, was obtained from the first half and applied to the remaining half of the data to obtain an independent assessment of its validity.

Variation in probing weights was an inevitable result of fixed weekly probing schedules and variation in growth rates. Thus, two approaches were utilized to determine the target weight to which adjustment was made in each method.

In the first instance, within pig regressions of BF on WT were used to predict BF at 5 kg intervals from 75 to 105 kg for each boar. The necessary within pig regressions were obtained using both a linear and a linear plus quadratic model. The linear model was:

$$Y_i = u + b_1WT + e_i$$

and the linear plus quadratic model was:

$$Y_i = u + b_1WT + b_2WT^2 + e_i$$

where:

Y_i = BF value of the i^{th} boar

u = overall mean

b_1 = regression coefficient of BF on WT

b_2 = regression coefficient of BF on WT^2

e_i = random error

The model which appeared to best represent the relationship between BF and WT over this weight range was used to derive predicted BF values at each of the 5 kg weight intervals. Adjustment was then made via Methods I and II to 90 kg from each of the weights.

Validity of the adjustment procedures (Methods I and II) were examined according to the criteria defined by Taylor and Hazel (1955). Although the criteria as defined by these authors referred to adjustment of liveweight to a standard age, they should be appropriate to evaluating the adjustment of BF to a standard weight. The three requirements of suitable adjustment factors listed by these authors were:

1. the method must be accurate in the sense that the adjusted values agree as closely as possible with the actual values at the standard weight to which adjustment is made.
2. the variance of the adjusted values should be approximately equal to the variance at the standard weight.
3. the adjustment procedure must be convenient for practical application.

Examples of this approach have been given by Quijandria and Robison (1971), Standal (1973) and Vangen and Robison (1977).

The second means by which BF adjustments were studied had the advantage of utilizing directly the actual BF measurements at the weight to which adjustment was made rather than relying on predicted values. In this procedure, the recorded weight of each boar closest to 90 kg was designated as the "target" weight. Adjustment was then made to this weight from each of the remaining weights via Method I and Method II. The deviations of the adjusted BF values, as derived via Method I and Method II, from the actual BF measured at the "target" weight were regressed on the deviations of the weights from the target weight. Thus the deviations from all pigs were pooled even though not all were adjusted to the same weight. Regressions were derived separately for forward and backward adjustment, as well as over the entire weight range (i.e. from first to last recorded weight).

In addition, deviations in weight from the target weight were coded into 5 kg increments (Table VII-1) and the mean deviations in backfat for each of Methods I and II were calculated for each weight deviation class. In this way the two methods could be compared according to the criteria of Taylor and Hazel (1955) described previously.

The tables provided by the ROP program for age adjustment allowed for adjustment to be made only to 90 kg. Therefore, age adjustments were examined by regressing age on WT on a within pig basis and using the resulting regression equations to predict ages at 75, 80, 85, 90, 95, 100 and 105 kg. This was similar to the first method described previously for study of the BF adjustment. Again both a linear and a linear plus quadratic model were used with the "best" model being used for prediction purposes. The adjustment procedure was evaluated using the criteria defined by Taylor and Hazel (1955).

Growth patterns were derived for each pig in a manner similar to that used to derive predicted age values. However, in this case WT was regressed on age to correspond with the standard method of describing growth curves.

The regressions of BF on WT and WT on age yielded separate regression equations for each pig and indicated the rate of backfat deposition and growth on an individual basis. The resulting intercepts and slopes of these regression equations were added to the record of each pig and were analysed as continuous variables in an analysis of variance. Breed, BF level and rate of growth were examined for their effects on the intercepts and slopes of the regressions of BF on WT while breed and BF level were examined for their effects on the intercepts and slopes of the regressions of WT on age. Growth classes were defined according to average daily gain (ADG) over the range of the data with class 1 containing those boars with ADG values below average and class 2 those boars with ADG values above average during this period. BF classes were coded according to predicted BF at 90 kg with class 1 containing those boars which were below average for this trait and class 2 those boars which were above average. The model for the analysis of intercepts and slopes of the within pig regressions of BF on WT was thus:

$$Y_{ijkl} = u + B_i + T_j + G_k + BT_{ij} + e_{ijkl}$$

where:

Y_{ijkl} = the intercept or slope of the regression of BF on WT within the l^{th} pig of the k^{th} growth class and the j^{th} BF class and the i^{th} breed
u = overall mean
B_i = effect of the i^{th} breed
T_j = effect of the j^{th} BF class
G_k = effect of the k^{th} growth class
BT_{ij} = interaction between the i^{th} breed and the j^{th} BF class
e_{ijkl} = random error

Preliminary analysis indicated that the other interactions (i.e. BG_{ik}, TG_{jk} and BTG_{ijk}) were not significant ($P>0.05$) and these effects were therefore not included in the model.

The model for the analysis of intercepts and slopes of the within pig regressions of WT on age was:

$$Y_{ijk} = u + B_i + T_j + BT_{ij} + e_{ijk}$$

where:

Y_{ijk} = the intercept or slope of the regression of WT on age within the kth pig of the jth BF class and the ith breed

u = overall mean

B_i = effect of the ith breed

T_j = effect of the jth BF class

BT_{ij} = interaction between the ith breed and the jth BF class

e_{ijk} = random error

C. RESULTS

The within pig regression analyses of BF on WT indicated that for only one boar was the inclusion of a quadratic term significant ($P<0.05$). Therefore, it was concluded that the regression of BF on WT over this weight range was essentially a linear one and the linear regression of BF on WT was used to derive predicted BF values for each boar at 75, 80, 85, 90, 95, 100 and 105 kg. The R^2 values on a within pig basis ranged from 26.9% to 99.0% with an average value of 80.8% indicating that in most boars a large proportion of the variation in BF was explained by variation in WT.

An examination of the least squares means of BF classes and ADG classes for BF and ADG (breeds separate) revealed that Yorkshires were superior ($P<0.05$) to Lacombes in both traits (Table VII-2).

The slopes of the within pig regressions of BF on WT were not significantly different ($P>0.10$) between the two breeds but due to the higher levels of BF in the Lacombes (Table VII-2) the intercepts were significantly different ($P<0.01$) (Table VII-3). Neither the slopes nor the intercepts of the regression lines were significantly different ($P>0.05$) between ADG classes indicating that boars with different growth rates tended to deposit fat at similar rates relative to weight. However, BF class did have a significant effect ($P=0.01$) on the slope of the within pig regression equations with boars having higher levels of BF at 90 kg exhibiting greater rates of backfat deposition (Table VII-4). This observation suggested that backfat deposition may have been a function of both weight and the amount of backfat carried by a boar. However, the presence of a significant ($P<0.01$) breed by BF class interaction (Table VII-3) indicated that this relationship was not present in both breeds.

A possible explantion for this discrepancy could be that it was due in part to the greater range in BF values in the Yorkshire breed. The maximum BF measurement observed among the Yorkshire boars was 6.3 mm above the mean BF value for the breed while the minimum was 5.7 mm below the mean. The corresponding maximum and minimum among the Lacombe boars were 3.0 mm and -4.4 mm. This difference in the BF ranges for the two breeds could have been the cause of the interaction (breed by BF class) observed.

While the present ROP backfat adjustment procedure does take into account differences in absolute backfat levels by assuming a greater rate of backfat deposition for higher backfat levels at a given weight, the assumption of a zero intercept is not supported in this study. This is evinced by examination of the least squares means of the intercepts of the various effects (Table VII-4). All were positive and significantly different ($P<0.01$) from zero except in the fatter BF class of the Yorkshire breed. Thus, forcing the regression equation to pass through a zero intercept when the actual intercept was greater than zero would imply a greater rate of BF deposition than was actually the case. This would have the effect of over-adjusting BF when adjustment was made in a forward direction and under-adjusting when adjustment was made in a backward direction. This hypothesis is supported by examination of the trend in adjusted BF values when adjustment of predicted BF was made to 90 kg from each of the weights 75, 80, 85, 90, 95, 100 and 105 kg (Table VII-5). The difference in adjusted BF values over this range amounted to 1.7 mm in the Yorkshire breed, 2.7 mm in the Lacombe breed and 2.0 mm in the combined data.

The deviations between adjusted predicted BF and actual predicted BF at 90 kg were slightly larger in respect to forward adjustment compared to backward adjustment. The absolute value of the deviations of adjusted BF from the actual value was 1.0 mm and 1.6 mm in the Yorkshire and Lacombe breeds, respectively, when forward adjusted from 75 kg, and 0.7 mm and 1.1 mm in these two breeds when backward adjusted from 105 kg. These differences were not large enough to ascertain asymmetry in the deviations, but they were suggestive of such.

These observations suggest that it would be prudent to adjust BF values along a regression line which more closely represents the actual rate of backfat deposition than does the ROP procedure. Based on the criteria of Taylor and Hazel (1955), Method II appeared to be a more effective adjustment procedure (Table VII-6). Although a large amount of variation resulted from both adjustment methods due to the low numbers of animals involved, the mean adjusted BF at each of the weights showed no definite trend in regards to forward versus backward adjustment in either breed or in the combined data when adjustment was made via Method II.

The second procedure employed to study BF adjustment methods indicated that regressions of BF deviations (adjusted BF via Method I - actual BF) on weight deviations were not significantly different ($P>0.05$) between forward and backward adjustment to the "target" weight in either breed or in the combined data (Table VII-7). Over the entire range of weight deviations there was a significant ($P<0.01$) increase in BF deviation as weight diverged from zero in either direction with the magnitude of the BF deviations being of opposite sign for forward and backward adjustment. The magnitude of the regression coefficients were similar for both breeds. For breeds combined, the overall regression of BF deviation on weight deviation was -0.065 mm/kg. At the extreme ends of the 75-105 kg range this would represent a difference of 1.95 mm in adjusted BF values.

Classification of the observations according to deviation of weight from "target" weight showed clearly not only the downward trend in BF deviations but also the trend in the variance associated with each class (Table VII-8). The variation of BF deviations was almost four times as large in boars which were more than 15 kg above or below the target weight as in those within 5 kg of this weight. This suggests that at the extreme ends of the weight range approximately a third of the boars would have adjusted backfat values more than 2.0 mm in error.

Adjustment of BF via Method II resulted in negative regressions of BF deviation on WT deviation (-0.027 for Yorkshires, -0.029 for

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Landrace and -0.028 for breeds combined) which were significant ($P<0.05$) only for breeds combined (Table 9). The magnitude of the regression coefficients derived via Method II were less than half those for the relevant regression coefficients derived via Method I from the same half of the data in both breeds and in the combined data.

Applying the criteria of Taylor and Hazel (1955) to the coded weight deviations (Table VII-10), it appeared as though Method II was superior to that of Method I in terms of trends in the means of the coded weight deviation classes. However, the large standard deviations associated with both methods indicated that while Method II tended to reduce the bias in adjusted values relative to weight, both methods left much to be desired in terms of accurately predicting actual BF at the target weight.

In respect to growth patterns, the regressions of WT on age indicated that the relationship between these two variables was essentially linear over the weight range studied. Seven of the 55 boars showed significant ($P<0.05$) quadratic terms but the additional amount of variation explained by the quadratic term was less than 2% in all cases. The R^2 values for the linear model ranged from 93.3% to 99.9%. This is not an unexpected observation for although the growth curve would be expected to exhibit a classical sigmoid curve over a wider weight range, the relationship should be nearly linear over a range bordering the inflection point (Forest et al 1975; Fitzhugh 1976). Therefore, predicted ages at each weight 75, 80, 85, 90, 95, 100 and 105 were derived using the within pig linear regression of age on WT (the inverse of the growth pattern equation).

Analysis of variance indicated that both intercepts and slopes of the within pig regression equations of age on WT approached significance at the 5% level for the breed effect while this was true only for the slopes of the BF class effect (Table VII-11). The least squares means of breeds and BF classes (Table VII-12) indicated that the Yorkshire boars had superior rates of growth compared to the Lacombes while the fatter BF class was associated with more rapid growth. However, while rapid growth was associated with higher BF within both breeds, this relationship was not apparent across breeds. For while Yorkshires tended to grow more rapidly they were also shown in Table VII-2 to have lower levels of BF on average than the Lacombes.

Adjusted age values derived via the ROP adjustment tables tended to exhibit an upward trend relative to weight in both breeds (Table VII-13) though the deviations of adjusted and predicted values did not appear to be symmetrical over the entire weight range. Forward adjustment by 15 kg resulted in underestimation of age by 1.3 and 1.4 days in the Yorkshires and Lacombes, respectively, while backward adjustment overestimated this trait by 2.6 days in the Yorkshire breed and 2.5 days in the Lacombe breed. However, these differences were relatively small compared to the overall variation in the adjusted age values. Therefore, the conclusion was that the adjustment procedure did a reasonably effective job of predicting age at 90 kg.

D. DISCUSSION

The allometric equation $Y=aX^b$ used by Huxley (1932) to describe the growth of body parts relative to the rest of the body has been widely used to quantify the rate of tissue growth in various species (Elsley et al. 1964; Berg and Butterfield 1966; Mukhoty and Berg 1971; Davies 1974; Kempster and Evans 1979). With regards to swine, weight of fat as a percentage of liveweight has been shown to increase with liveweight (Cuthbertson and Pomeroy 1962; Richmond and Berg 1971a).

Jones et al. (1980) reported that subcutaneous fat of pigs relative to total side fat had a growth coefficient not significantly different from unity. That the relationship between subcutaneous fat and total fat in pigs would be close to unity is not surprising considering that this depot has been reported to account for upwards of 84% of total fat (Richmond and Berg 1971b). Therefore, in pigs, the weight of subcutaneous fat relative to liveweight would exhibit a growth coefficient similar to that of total fat.

This suggests a nonlinear relationship between subcutaneous fat and body weight and appears to contradict the linear relationship between backfat and liveweight reported in the present study. The discrepancy, of course, pertains to the method of measuring backfat. On a weight to weight basis, subcutaneous fat deposition would be expected to follow a pattern described by the allometric equation with a growth coefficient greater than unity. However, when subcutaneous fat is measured as backfat depth the same relationship would not be expected to apply. As subcutaneous fat is laid down over an ever increasing surface area, a linear increase in backfat depth relative to weight does not imply a linear relationship between total subcutaneous fat weight and body weight.

Although the two breeds examined in this study differed significantly ($P<0.05$) for BF at 90 kg, there was no indication of a significant difference between the rate at which backfat was deposited in the two breeds. Jones et al (1980) in a study involving serial slaughtering also reported similar rates of fat deposition between breed crosses. They suggested that the differences observed in fatness adjusted to a standard total side muscle weight could be due to differences in the commencement of rapid fattening at different muscle weights rather than to differences in the rate of fattening. This being the case, the use of a single equation for adjustment of BF to a standard liveweight for use across breeds should prove satisfactory. The problem, then, is to derive an equation which will best perform this task.

The large amount of variation observed in the rate of backfat deposition among individual boars makes it difficult for any one adjustment procedure to be applied effectively across a population. Although there was an indication that the level of BF might be associated with the rate of BF deposition in the Yorkshire breed (i.e. a tendency for fatter boars to deposit BF at greater rates) this relationship was not apparent in the Lacombe breed nor did it exist between breeds. The Lacombe boars were significantly fatter ($P<0.05$) than the Yorkshires yet they tended to deposit fat at a slower rate (i.e. 0.166 mm/kg vs. 0.190 mm/kg) which approached significance ($P=0.11$). While these data suggest that proportional backfat adjustments (i.e. in relation to existing fatness) might be appropriate, it should be noted that the ROP adjustment procedure which employs that principle exhibited a larger degree of bias than an adjustment procedure which applied a common rate of backfat deposition to all boars.

The results in this study support the hypothesis that, for accurate genetic comparisons of backfat among potential breeding animals, it is essential to measure this trait at a standard weight for all pigs evaluated.

Although ages should also be obtained directly at a standard weight in all animals, the present ROP adjustment procedure for age was shown to be a relatively effective means of predicting age at 90 kg and was a more accurate procedure than that used for backfat adjustment.

Table VII-1. Deviations of the weights at which BF was measured from the weights to which adjustment was made (i.e. "target" weight) for each of the coded weight classes

WEIGHT CLASS	DEVIATION FROM "TARGET" WEIGHT (kg)
1	< - 15
2	-15 - -10
3	-10 - -5
4	-5 - +5
5	+5 - +10
6	+10 - +15
7	> + 15

Table VII-2. Least squares means (with standard errors in parenthesis) of predicted average backfat at 90 kg (mm) and ADG (kg) for boars classified as being above or below average for these traits (class 1 = below average, class 2 = above average)

TRAIT	BREED	CLASS 1	CLASS 2	BOTH CLASSES
Predicted Backfat	Yorkshire	19.3 (0.4) a[+]	23.8 (0.4)	21.6 (0.3) a
	Lacombe	20.8 (0.5) b	24.8 (0.5)	22.8 (0.4) b
ADG	Yorkshire	0.95 (0.02)	1.17 (0.02) a	1.06 (0.01) a
	Lacombe	0.92 (0.03)	1.05 (0.03) b	0.98 (0.02) b

[+] means in the same column within a trait with different letters are significantly different ($P<0.05$)

Table VII-3. Probability levels derived from analysis of variance of the intercepts and slopes of the within pig regression equations of BF on WT

SOURCE	PROBABILITY OF GREATER F-VALUE	
	INTERCEPT	SLOPE
Breed	0.01	0.11
BF Class	0.80	0.01
ADG Class	0.55	0.50
Breed x BF Class	0.00	0.00

Table VII-4. Least squares means (with standard errors in parenthesis) of the intercepts (mm BF) and slopes (mm BF/kg) of the within pig regressions of BF on WT for breed, BF class, ADG class and breed x BF class interaction

SOURCE	SUBCLASS	INTERCEPT	SLOPE
Breed	Yorkshire	4.4 ** (0.7)	0.190 ** (0.009)
	Lacombe	7.9 ** (1.0)	0.166 ** (0.012)
BF class	1	6.0 ** (0.9)	0.156 ** (0.011)
	2	6.3 ** (0.9)	0.200 ** (0.011)
ADG class	1	6.6 ** (0.9)	0.173 ** (0.011)
	2	5.8 ** (0.9)	0.183 ** (0.011)
Breed x BF class	Yorkshire x 1	6.9 ** (1.0)	0.137 ** (0.012)
	Yorkshire x 2	2.0 (1.1)	0.243 ** (0.013)
	Lacombe x 1	5.1 ** (1.4)	0.175 ** (0.018)
	Lacombe x 2	10.7 ** (1.5)	0.156 ** (0.018)

** significantly different than zero (P<0.05)

Table VII-5. Means (with standard deviations in parenthesis) of BF adjusted to 90 kg via Method I and the deviation (DEV) of each adjusted value from BF at 90 kg

BREED	WT	BF	ABF	DEV
Yorkshire	75	18.5 (2.1)	22.2 (2.5)	1.0
	80	19.4 (2.3)	21.8 (2.6)	0.6
	85	20.3 (2.6)	21.5 (2.8)	0.3
	90	21.2 (2.9)	21.2 (2.9)	0.0
	95	22.1 (3.2)	21.0 (3.0)	-0.2
	100	23.1 (3.5)	20.8 (3.2)	-0.4
	105	24.0 (3.8)	20.5 (3.3)	-0.7
Lacombe	75	20.3 (2.5)	24.4 (3.0)	1.6
	80	21.2 (2.4)	23.8 (2.7)	1.0
	85	22.0 (2.4)	23.3 (2.5)	0.5
	90	22.8 (2.4)	22.8 (2.4)	0.0
	95	23.7 (2.4)	22.4 (2.3)	-0.4
	100	24.5 (2.5)	22.1 (2.2)	-0.7
	105	25.3 (2.6)	21.7 (2.2)	-1.1
Breeds Combined	75	19.1 (2.4)	22.9 (2.9)	1.1
	80	20.0 (2.5)	22.5 (2.8)	0.7
	85	20.9 (2.6)	22.1 (2.8)	0.3
	90	21.8 (2.8)	21.8 (2.8)	0.0
	95	22.6 (3.0)	21.5 (2.9)	-0.3
	100	23.5 (3.3)	21.2 (2.9)	-0.6
	105	24.4 (3.5)	20.9 (3.0)	-0.9

Table VII-6. Means (with standard deviations in parenthesis) of BF adjusted to 90 kg via Methods I and II and the deviation (DEV) of each adjusted value from BF at 90 kg

			METHOD I		METHOD II	
BREED	WT	BF	ABF	DEV	ABF	DEV
Yorkshire	75	18.1 (1.8)	21.8 (2.2)	0.0	20.7 (1.8)	-1.1
	80	19.8 (2.5)	22.3 (2.8)	0.5	21.6 (2.5)	-0.2
	85	19.8 (2.4)	21.0 (2.6)	-0.8	20.7 (2.4)	-1.1
	90	21.8 (3.0)	21.8 (3.0)	0.0	21.8 (3.0)	0.0
	95	21.4 (3.1)	20.3 (2.9)	-1.5	20.6 (3.1)	-1.2
	100	23.8 (3.5)	21.4 (3.2)	-0.4	22.1 (3.5)	0.3
	105	23.1 (3.8)	19.8 (3.2)	-2.0	20.5 (3.8)	-1.3
Lacombe	75	20.0 (2.2)	24.0 (2.6)	0.7	22.6 (2.2)	-0.7
	80	21.5 (2.7)	24.2 (3.0)	0.9	23.3 (2.7)	0.0
	85	21.6 (2.3)	22.9 (2.4)	-0.4	22.5 (2.3)	-0.8
	90	23.3 (2.5)	23.3 (2.5)	0.0	23.3 (2.5)	0.0
	95	23.2 (2.4)	22.0 (2.3)	-1.3	22.4 (2.4)	-0.9
	100	25.0 (2.5)	22.5 (2.2)	-0.8	23.2 (2.5)	-0.1
	105	24.8 (2.6)	21.3 (2.3)	-2.0	22.2 (2.6)	-1.2
Breeds Combined	75	18.8 (2.1)	22.5 (2.6)	0.2	21.4 (2.1)	-0.9
	80	20.4 (2.6)	22.9 (3.0)	0.6	22.1 (2.6)	-0.2
	85	20.4 (2.5)	21.6 (2.6)	-0.7	21.3 (2.5)	-1.0
	90	22.3 (2.9)	22.3 (2.9)	0.0	22.3 (2.9)	0.0
	95	22.0 (3.0)	20.9 (2.8)	-1.4	21.2 (3.0)	-1.1
	100	24.2 (3.2)	21.8 (2.9)	-0.5	22.4 (3.2)	0.1
	105	23.7 (3.5)	20.3 (3.0)	-2.0	21.1 (3.5)	-1.2

Table VII-7. Regression coefficients (b) (with standard errors in parenthesis) of BF deviations derived via Method I (i.e. adjusted BF - actual BF) on WT deviations (i.e. WT - "target" weight), the R^2 values and the probability levels (P) associated with tests of homogeneity of the slopes of forward and backward adjustment

WEIGHT DEVIATION	YORKSHIRE			LACOMBE			BREEDS COMBINED		
	b	R^2(%)	P	b	R^2(%)	P	b	R^2(%)	P
<0	-0.060 (0.039)	2.5	0.47	-0.062 (0.048)	4.0	0.87	-0.059 (0.030)	2.7	0.61
>0	-0.031 (0.019)	2.0		-0.069** (0.020)	15.5		-0.043 (0.014)	4.3	
All	-0.060** (0.009)	15.4		-0.078** (0.011)	33.2		-0.065** (0.007)	19.4	

** significantly different than zero ($P<0.01$)

Table VII-8. Means and standard deviations (SD) of BF deviations derived via Method I (i.e. adjusted BF - actual BF) for classes coded according to deviations of WT from "target" weight

CLASS	DEVIATION FROM "TARGET" WEIGHT (kg)	Yorkshire			Lacombe			Breeds Combined		
		n	MEAN	SD	n	MEAN	SD	n	MEAN	SD
1	< -15	36	1.31	2.38	14	1.49	1.94	50	1.36	2.25
2	-15 to -10	23	1.19	2.34	8	1.46	1.49	31	1.26	2.13
3	-10 to -5	33	0.73	1.80	20	0.87	1.50	53	0.78	1.68
4	-5 to +5	44	-0.01	0.46	22	0.17	0.72	66	0.05	0.56
5	+5 to +10	34	-0.58	2.04	17	-0.61	1.17	51	-0.59	1.78
6	+10 to +15	25	-0.77	1.26	13	-1.01	1.70	38	-0.85	1.41
7	> +15	36	-0.65	2.14	15	-1.10	1.13	51	-0.78	1.90

Table VII-9. Regression coefficients (with standard errors in parenthesis) of BF deviations derived via Methods I and II (i.e. adjusted BF - actual BF) on WT deviations (i.e. WT - "target" weight) and the R^2 values

ADJUSTMENT METHOD	YORKSHIRE		LACOMBE		D	
	REGRESSION COEFFICIENT	R^2 (%)	REGRESSION COEFFICIENT	R^2 (%)	REGRESSION COEFFICIENT	R^2 (%)
I	-0.071 (0.016) **	15.1	-0.082 (0.017) **	32.5	-0.074 (0.012) **	18.5
II	-0.027 (0.017)	2.4	-0.029 (0.017)	5.2	-0.028 (0.013) *	2.8

* significantly different than zero ($P<0.05$)
** significantly different than zero ($P<0.01$)

Table VII-10. Means (with standard deviations in parenthesis) of BF deviations derived via Methods I and II for classes ded according to deviation of WT from "target" weight

BREED	ADJUSTMENT METHOD	CLASS 1	2	3	4	5	6	7
Yorkshire	I	1.81 (2.84)	1.81 (2.85)	0.70 (2.23)	-0.03 (0.28)	-0.18 (2.65)	-1.15 (1.29)	-0.04 (2.69)
	II	0.78 (2.83)	1.19 (2.89)	0.39 (2.28)	-0.03 (0.30)	0.07 (2.69)	-0.76 (1.70)	0.65 (2.85)
Lacombe	I	1.85 (2.00)	1.79 (1.31)	1.05 (1.61)	0.33 (1.06)	-0.36 (1.20)	-0.59 (2.17)	-1.16 (0.96)
	II	0.81 (1.88)	0.96 (0.98)	0.55 (1.51)	0.36 (1.14)	0.02 (1.28)	-0.25 (2.46)	-0.20 (1.39)
Breeds Combined		1.82 (2.62)	1.81 (2.51)	0.84 (1.97)	0.08 (0.64)	-0.24 (2.19)	-0.99 (1.56)	-0.44 (2.2[illegible])
	II	0.79 (2.60)	1.13 (2.52)	0.46 (1.97)	0.09 (0.69)	0.05 (2.24)	-0.61 (1.90)	0.34 (2.42)
No. Observations								
Yorkshire		19	12	16	22	14	15	14
Lacombe		6	4	11	10	8	6	8
Breeds Combined		25	16	27	32	22	21	22

Table VII-11. Probability levels derived from analysis of variance of the intercepts and slopes of the within pig regression equations of liveweight on age

SOURCE	PROBABILITY OF GREATER F-VALUE INTERCEPT	SLOPE
Breed	0.06	0.06
BF Class	0.27	0.06
Breed x BF Class	0.20	0.63

Table VII-12. Least squares means (with standard errors in parenthesis) of the intercepts (kg) and slopes (kg/day) of the within pig regressions of liveweight on age for breed, BF class and breed x BF class interaction

SOURCE	SUBCLASS	INTERCEPT	SLOPE
Breed	Yorkshire	-52.4 (2.8)	1.051 (0.021)
	Lacombe	-43.1 (3.9)	0.978 (0.030)
BF class	1	-45.0 (3.3)	0.979 (0.026)
	2	-50.4 (3.5)	1.050 (0.027)
Breed x BF class	Yorkshire x 1	-46.6 (3.6)	1.006 (0.028)
	Yorkshire x 2	-58.2 (4.2)	1.095 (0.032)
	Lacombe x 1	-43.5 (5.5)	0.952 (0.043)
	Lacombe x 2	-42.7 (5.5)	1.005 (0.043)

Table VII-13. Means (with standard deviations in parenthesis) of age (days) adjusted to 90 kg via the ROP adjustment procedure and the deviation (DEV) of each adjusted value from age at 90 kg

BREED	WT	AGE	ADJUSTED AGE	DEV
Yorkshire	75	120.7 (8.6)	134.1 (9.4)	-1.3
	80	125.6 (8.6)	133.9 (9.2)	-1.5
	85	130.4 (8.8)	134.9 (9.1)	-0.5
	90	135.4 (8.9)	135.4 (8.9)	0.0
	95	140.2 (9.2)	136.2 (8.9)	0.8
	100	145.1 (9.5)	137.2 (9.0)	1.8
	105	150.0 (9.9)	138.0 (8.8)	2.6
Lacombe	75	122.8 (7.8)	136.4 (8.7)	-1.4
	80	127.8 (8.1)	136.4 (8.6)	-1.4
	85	132.8 (8.4)	137.3 (9.0)	-0.5
	90	137.8 (8.7)	137.8 (8.7)	0.0
	95	142.7 (9.0)	138.6 (8.8)	0.8
	100	147.7 (9.3)	138.9 (8.7)	1.1
	105	152.7 (9.6)	140.3 (8.8)	2.5

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VIII. THE SENSITIVITY OF A TWO TRAIT SELECTION INDEX TO CHANGES IN ECONOMIC WEIGHTS AND GENETIC PARAMETER ESTIMATES[1].

A. INTRODUCTION

Construction of a selection index to aid in the improvement of livestock for several traits was presented by Hazel (1943). In theory, use of the index provides for maximum genetic progress in aggregate genotype defined as the sum of the genotypes for the component traits, each weighted according to its relative economic value. Maximum genetic progress is possible only if the parameters used in construction of the index are accurately estimated (Sales and Hill 1976; Vandepitte and Hazel 1977) and, as noted by Harris (1964) and Hayes and Hill (1980), these parameter estimates can seldom be considered free of error. However, errors in parameter estimation may result in only slight losses in efficiency. Fowler et al (1976), for example, found that the efficiency of an index combining seven economic traits did not drop more than 2% in any case from a 50% error in the economic weight of any one trait. Efficiency dropped no more than 3% and 0.6%, respectively, from errors in estimates of genetic correlations and heritabilities. These results, confirmed by Sales and Hill (1976) and Vandepitte and Hazel (1977), indicate that the selection index is highly robust with respect to economic weights and genetic parameter estimates. Larger changes in economic weights, omission of important traits, undue emphasis on unimportant traits and reversal of selection for an important trait may lead to large losses

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[1] A version of this chapter has been published. Allan, B.B., Fredeen, H.T. and Weiss, G.M. 1985. Can. J. Anim. Sci. 65:21.

in efficiency (Smith 1983), and sampling errors can substantially reduce efficiency when the population under selection is small (Harris 1964).

The Canadian swine Record of Performance (ROP) program has in recent years changed from use of a three trait genetic index to a two trait phenotypic index for evaluating boars. The present index utilizes phenotypic measurements of a boar's performance on test for average daily gain (ADG) and average adjusted backfat depth (BF). This method, which ignores genetic and economic parameters in the calculation of a boar's index value, is equivalent to assuming that the traits in the index have equal heritabilities, equal economic values (per standard deviation) and that correlations, both genetic and phenotypic, among traits in the index are zero. Deviation of the actual population parameters from these assumptions would be expected to result in some loss in efficiency of selection, and the magnitude of this loss would be dependent on the sensitivity, or conversely the robustness, of the index to errors in parameter estimates.

This study examines the effects of variation in the economic weights and genetic parameters used in construction of a selection index for swine, employing measurements of two traits, ADG and BF, on response in aggregate genotype. The results of the study will be used to determine if sacrifices in terms of genetic or economic progress are being made by the use of an index employing only phenotypic measurements for boar evaluation in the Canadian swine ROP program.

B. MATERIALS AND METHODS

The records of 590 Yorkshire boars tested at the New Hamburg, Ontario ROP test station in 1977 and 1978 provided the data base for this study. These records comprised only those boars tested as full sib pairs. Measurements on individual animals were expressed as deviations from the contemporary average defined as the average of Yorkshire boars in the same station fill. There was one fill per month and 21 such contemporary groups were represented in the data ranging in size from 6 to 48 boars.

A selection index value was calculated for each boar based on its individual performance. The coefficients of the index varied in each of several studies which are described later.

The boars were ranked based on their index values and the highest indexing 10% selected as potential parental stock. This proportion was chosen as being representative of a fairly rigorous selection program and would be expected to accentuate variation in genetic progress resulting from variation in parameter estimation. From this selected group, the expected genetic response in each trait was determined as the mean standardized deviation (intensity of selection) of the selected group multiplied by the estimated heritability for that trait and divided by two to reflect the assumption that the boars would be mated to females of average genetic merit. Genetic response was calculated for the two component traits of the index (ADG and BF) as well as for feed conversion (FC) because of its economic importance and its correlation with ADG.

The expected genetic responses (in standard deviation units) in each trait were then summed to express the total response to selection as was done by Baker (1974). This sum (ADG+BF+FC) represented the expected net genetic response of the aggregate genotype. The genetic response for each trait was also multiplied by an estimated economic value per standard deviation (SD) unit (\$2.19 per SD_{ADG}, \$1.66 per SD_{BF}, \$1.51 per SD_{FC}) and these products were summed to arrive at the economic value of the expected genetic response of the aggregate genotype. The economic values used reflected the present economic situation. The value of ADG was calculated from estimates of Garnett (1975) with variable costs assumed to have increased by 50% and interest rates doubled. The value for fat was based on the relationship between fat and index using a 73 kg. carcass at a market price of \$1.65 per kg. Feed conversion value was calculated based on a feed cost of \$180 per tonne. The economic value of the genetic response of the aggregate genotype represented the potential increase in average profit (i.e. increased carcass value, decreased production costs) per pig produced by the selected boars on the assumption they would be mated with sows of average genetic merit. For example, should selection from the use of a particular index result in the aggregate genotype having a genetic response worth \$0.90 this would mean that the boars selected using this index would produce market hogs yielding on average \$0.90 greater profit per hog than a group of market hogs produced by a randomly selected group of boars from the same population.

Genetic and phenotypic parameters were obtained from a study by Fredeen et al. (1980) involving the records of 14,811 ROP station tested boars penned as full sib pairs between 1973 and 1979 (Table VIII-1). These estimates are over the five majority breeds (Yorkshire, Landrace, Lacombe, Hampshire, Duroc) and were based on the sire component obtained from a nested analysis of variance for full sibs. The model used was sires>dams>error. The corresponding phenotypic standard deviations obtained from this study were:

SD_{ADG} = 0.078 kg/day
SD_{BF} = 1.9 mm
SD_{FC} = 0.07

The genetic parameters thus obtained are consistent with literature estimates and were considered appropriate estimates of the true parameters of the population from which this sample was drawn. However, as the heritability estimates for ADG and BF were based on individual measurements while the estimate for FC was based on a pen average of two boars, it was necessary to convert the heritability estimate for FC to an individual basis to make all estimates comparable. Falconer (1981) expresses the relationship between heritability of family means (h^2_f) and heritability of individual measurements (h^2) as:

$$h^2 = h^2_f \ (1+(n-1)r \ / \ 1+(n-1)t)$$

where:

n = the number of individuals in the families (two in this case)
r = the correlation of breeding values (assumed to be 0.5 for full sibs)
t = the phenotypic correlation between family members (in the absence of estimates of the variance due to dominance and common environment t is assumed to equal $0.5h^2$)

This produces an estimate of h^2 for FC on an individual basis of 0.36.

The above genetic and phenotypic estimates were used both in the calculation of expected genetic response and in the calculation of index coefficients.

The two trait index used in selecting the boars had the form:

$$I = 100 + b_{ADG}(ADG-ADG_{MEAN}) + b_{BF}(BF-BF_{MEAN})$$

where:

b_{ADG}, b_{BF} = the selection index coefficients (Hazel 1943)

ADG_{MEAN}, BF_{MEAN} = contemporary group averages for ADG and BF, respectively

b_{ADG} and b_{BF} were calculated on the basis of the following equation (Turner and Young, 1969):

$$[b] = [P]^{-1}[G][a]$$

where:

[illegible], [G] = the matrices of the phenotypic and genotypic variances and covariances

[a], [b] = vectors of economic weights and the index coefficients, respectively

For the purposes of this study, the weighting factors of the equation were altered to examine:

1. a range in the economic weights used in calculating the index coefficients while keeping the genetic and phenotypic parameters constant. The ratio of economic weights expressed as dollar value per unit ADG : dollar value per unit BF (i.e. \$ per kg/day : \$ per mm fat) were varied from a ratio of 5:1 to 75:1. Note that the current estimates of the economic values of \$2.19 and \$1.66 per SD of ADG and BF respectively can be expressed in terms of units of the index by dividing each by its repective SD (based on the sample of 590 bo[illegible] $_{DG}=0.1$

kg/day, SD_{BF}=2.03mm). In this case the ratio \$2.19 per SD_{ADG} : \$1.66 per SD_{BF} is approximately equal to \$27 per kg/day ADG : \$1 per mm BF.

2. a range in relative heritabilities of the two traits while keeping the ratio of economic weights constant at 27:1 and with correlations absent. Ratios of heritabilities were varied from 0.625:1 (h^2_{ADG}:h^2_{BF}) to 1:1 as it was felt that this was a reasonable range within which the actual ratio of estimates might vary. (i.e. if h^2_{ADG}=0.31 and h^2_{BF}=0.40, their ratio is 0.775:1). Preliminary analysis indicated that the index coefficients produced by the calculations were dependent on the ratio of h^2_{ADG}:h^2_{BF} rather than on the absolute values of these estimates and for this reason the study was conducted over a range of heritability ratios rather than over a range of specific values.
3. the same as (2) but with correlations equal to 0.25.
4. the same as (2) but with the ratio of economic weights set to 50:1.

Finally, in each of the above studies, the net genetic response and the economic value of that response which would be expected using the weighting characteristics of an index employing only phenotypic measurements was compared to the response which would be expected using the weighting which would be incorporated in the construction of an index employing genetic and economic parameters as well.

The two levels of correlations used in these studies (zero vs. 0.25) were chosen to cover a range of literature estimates and, as was done by Smith (1983), the genetic and phenotypic correlations were assumed to be equal to reduce the number of combinations to be tested and because of the fact that they are often found to be similar in practice.

C. RESULTS

Varying the ratio of economic weights used to calculate the coefficients of the selection index while keeping the other parameters constant resulted in the genetic response of ADG increasing steadily at the expense of BF as the ratio of economic weights changed in favour of ADG (Fig. VIII-1). FC exhibited a response similar to that of ADG but at a lesser rate. These results are as expected and simply indicate that the boars comprising the selected group varied according to the weightings applied to the traits in the index. However, the flatness of the curve for expected aggregate genetic response and of the expected economic value of this response over a range of economic values from a ratio (ADG:BF) of about 15:1 to about 50:1 would seem to indicate that the economic outcome of the selection process using this type of index was relatively invariant over a wide range of economic values. The ratio of 15:1 (low limit of the plateau) represents an economic situation where production costs (excluding feed) have decreased by 30% relative to the present situation (27:1) and hog carcass value increased by the same percentage. The ratio at the other end of the plateau (50:1) represents the reverse situation in which production costs have risen by 30% and carcass value decreased by 30%. Even basing selection on a ratio of 15:1 when the actual ratio was 50:1 would not result in a large loss in the economic value of the expected genetic response compared to that which would be realized using the actual (50:1) ratio. Assuming the current estimates of the economic values of $2.19 and $1.66 per SD of ADG and BF, respectively, a ratio of 50:1 could result from either the value of ADG increasing or the value of BF decreasing. Given the two extremes (i.e. the value of one trait remaining constant and the other increasing or decreasing), a ratio of 50:1 on a unit basis would result from a ratio on a SD basis of $4.09:$1.66 or $2.19:$0.89. The difference in the economic value of the expected genetic response basing selection on a ratio of 15:1 would be only $0.19 and $0.10 less, respectively, than that which would [illegible]alized basing selection on a ratio of 50:1 (Table VIII-2). Given the extreme difference between these two ratios, the loss of economic gain is negligible.

When the ratio of economic weights was kept constant at its estimated value of 27:1, varying the ratio of the heritabilities of ADG:BF with zero genetic and phenotypic correlations had little impact on the expected genetic responses (Fig. VIII-2). Indeed, from a ratio of 0.625:1 to 1:1 the expected genetic response of ADG changed by only 0.03 SD units while that of BF changed by only 0.05 SD units. The upper curve of Fig. VIII-2, which illustrates the economic value of these changes shows that in terms of dollars/hog the variation in heritabilities over the range studied had very little effect.

Repeating the above study with genetic and phenotypic correlations assumed to be 0.25, the trends in genetic change of these traits (Fig. VIII-3) were similar to those in Fig. VIII-2. What changed was the point of intersection where the genetic response was the same in each trait. The upper curve of Fig. VIII-3 shows that the aggregate economic value of these responses was also relatively insensitive to the range of heritability ratios.

The previous two studies examined the effects of varying heritability ratios and correlations at the actual estimated ratio of economic weights. The final study was performed to determine whether varying the ratios of heritabilities would have a similar effect when the ratio of economic weights was extreme relative to the actual situation. In this study the ratio of economic weights used in calculating the index coefficients was 50:1 which represents a point on the outer edge of the plateau in Fig. VIII-1. This change in economic weights caused a divergence in the genetic responses of the two traits by placing a higher value on ADG at the expense of BF (Fig. VIII-4). However, even at this extreme ratio of economic values the difference in response from one end of the range to the other amounted to only about $0.09 per hog produced (upper curve of Fig. VIII-4). This indicated again that although different animals were being selected in each case, what was sacrificed in one trait was offset by gains in the other trait.

D. DISCUSSION

For the situations studied, aggregate genetic response and the economic value of that response from selection employing a two trait index were not highly sensitive to variation in economic and genetic parameters used in calculating the index coefficients. It was found that the relative economic values of the two traits in the index could vary over a wide range with little effect on the economic outcome. Similarly, variation of heritability ratios from 0.625:1 to 1:1 (ADG:BF) had only minor effects on the net economic consequence as did a range of genetic and phenotypic correlations from zero to 0.25. The studies also indicated that it is the ratio of heritabilities and economic weights used in calculating the index coefficients which are the important issue and not the absolute magnitude of those parameters.

One can conclude from these evaluations that precise estimates of population parameters are not necessary for the construction of a selection index. Indeed, a phenotypic index, with its fixed values of genetic and economic parameters, should result in economic progress very similar to that of a genetic index when used in a selection program.

In order to examine this latter point, the net genetic response, and the economic value of that response, which would be expected from using a phenotypic index was compared to the response which would be expected from using genetic indexes. These comparisons were made in each of the previous four studies (Table VIII-3). In the first study the genetic response which would be expected from using a ratio of economic weights of 1:1 on a SD basis (20:1 on a unit basis) would be 98% of that expected using the actual ratio of economic weights (27:1 on a unit basis). In economic terms, this amounted to only $0.04 less per hog produced. The results from the other studies were similar.

This indicates that incorporation of weightings characteristic of a phenotypic index in construction of a genetic index would result in only slight reductions in the overall profitability of the hogs produced. Thus, even when aggregate genetic response (ADG+BF+FC) was reduced by 6%, as in the fourth study, the economic loss was less than $0.05 per carcass. The reason for the very slight reduction in profitability may be more apparent by examining the actual differences in boars which were selected using the two indexes. In the fourth study, for example, 49 out of 60 boars selected from the total population of 590 boars were the same regardless of whether a heritability ratio of 0.625:1 or 1:1 ($h^2_{ADG}:h^2_{BF}$) was used in construction of the index. This seems to indicate the "best" boars in the population will tend to be identified and subsequently selected over a wide range of ratios of heritabilities and economic weightings used in index construction and, therefore, differences in genetic progress and differences in overall profitability are likely to be small.

From these results it is concluded that little sacrifice in terms of genetic or economic progress are being made by using a two trait phenotypic index rather than a two trait genetic index in the national swine ROP program. It has been demonstrated that the results from a strict phenotypic index which assumes equal heritabilities, equal economic values and the absence of correlations will be comparable to those produced by use of more sophisticated genetic and economic indexes.

Table VIII-1. Genetic and phenotypic parameters obtained from 14,811 ROP station-tested boars by Fredeen et. al. (1980) with heritability on the diagonal, phenoptypic correlations above and genetic correlations below

	ADG	BF	FC
ADG	0.31	0.19	-0.35
BF	0.23	0.40	0.17
FC	-0.45	0.12	0.44

Table VIII-2. Economic responses (sum of responses in ADG and BF) resulting from selection based on ratios of economic weights (on a unit basis) of 15:1 and 50:1 when actual ratio is 50:1

RATIO OF ECONOMIC WEIGHTS INCLUDED IN INDEX (kg.day ADG:mm BF)	ECONOMIC RESPONSE ($) RATIO OF ECONOMIC WEIGHTS ON A SD BASIS (SD_{ADG}:SD_{BF}) USED TO ESTIMATE ECONOMIC RESPONSE 4.09:1.66	 2.19:0.89
15:1	0.89	0.48
50:1	1.08	0.58
Difference	0.19	0.10

Table VIII-3. Expected genetic response (%R) at weightings typical of a phenotypic index as a percentage of the response expected at weightings typical of a genetic index and the value difference in dollars per hog (DIFF) of those responses (i.e. value of response at weightings typical of a phenotypic index − value of response at weightings typical of a genetic index)

FIGURE	WEIGHTING TYPICAL OF GENETIC INDEX	WEIGHTING TYPICAL OF PHENOTYPIC INDEX	%R	DIFF
1	ratio of economic weights = 27:1	ratio of economic weights = 20:1^{+}	98	-0.040
2	$h^2_{ADG}:h^2_{BF} = 0.775:1$	$h^2_{ADG}:h^2_{BF} = 1:1$	98	-0.010
3	$h^2_{ADG}:h^2_{BF} = 0.775:1$	$h^2_{ADG}:h^2_{BF} = 1:1$	98	-0.005
4	$h^2_{ADG}:h^2_{BF} = 0.775:1$	$h^2_{ADG}:h^2_{BF} = 1:1$	94	-0.045

$^{+}$ a ratio of economic weights (ADG:BF) of 20:1 on a unit basis (i.e. \$ per kg.day : \$ per mm) is equivalent to a ratio of 1:1 on a SD basis.

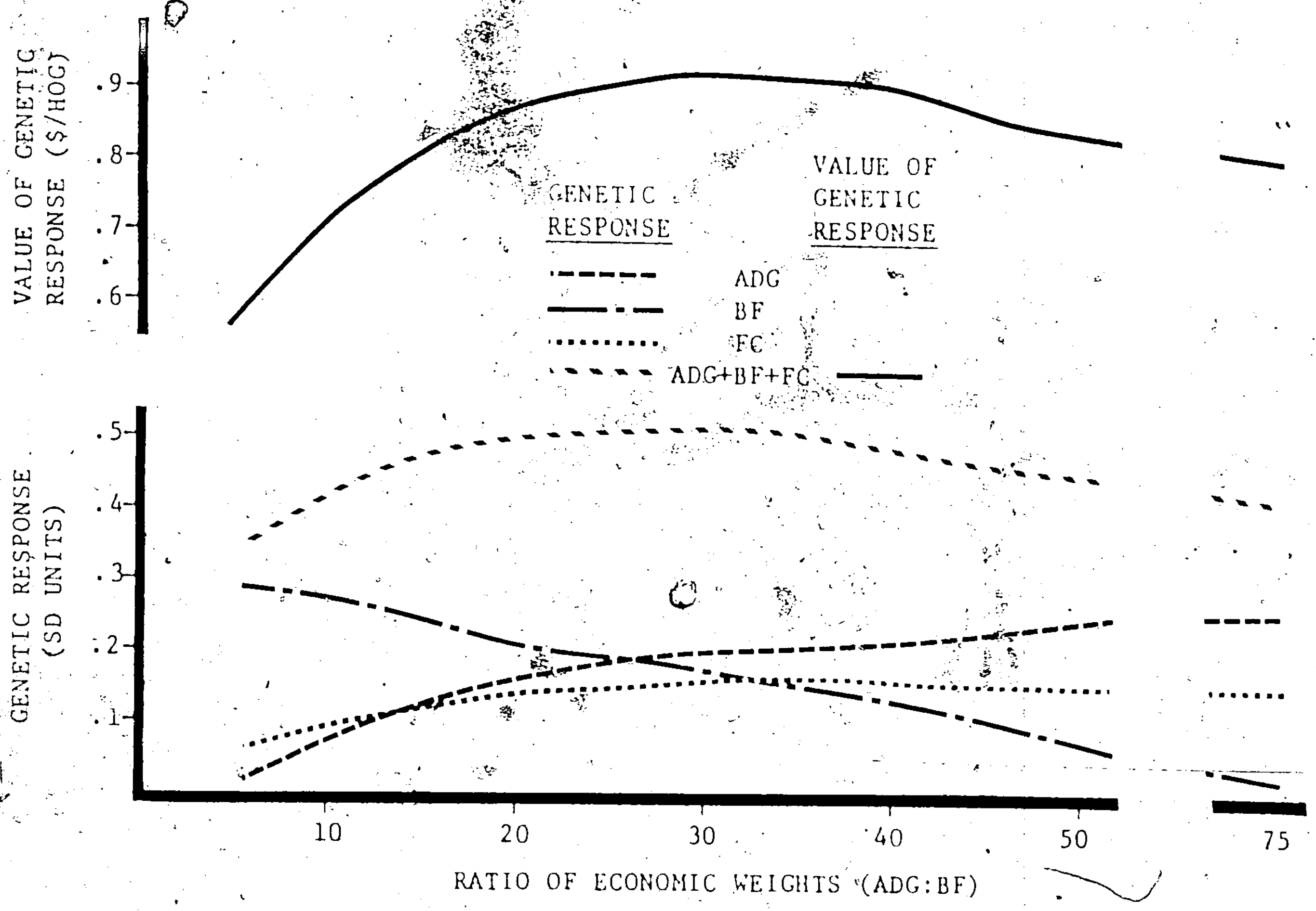

Fig. VIII-1. The effect of variation in the economic weights assigned to growth (ADG) and backfat (BF) in the ROP swine index on the genetic response of each component trait, of feed conversion (FC), of the aggregate genotype (ADG+BF+FC) and on the net economic value of that response.

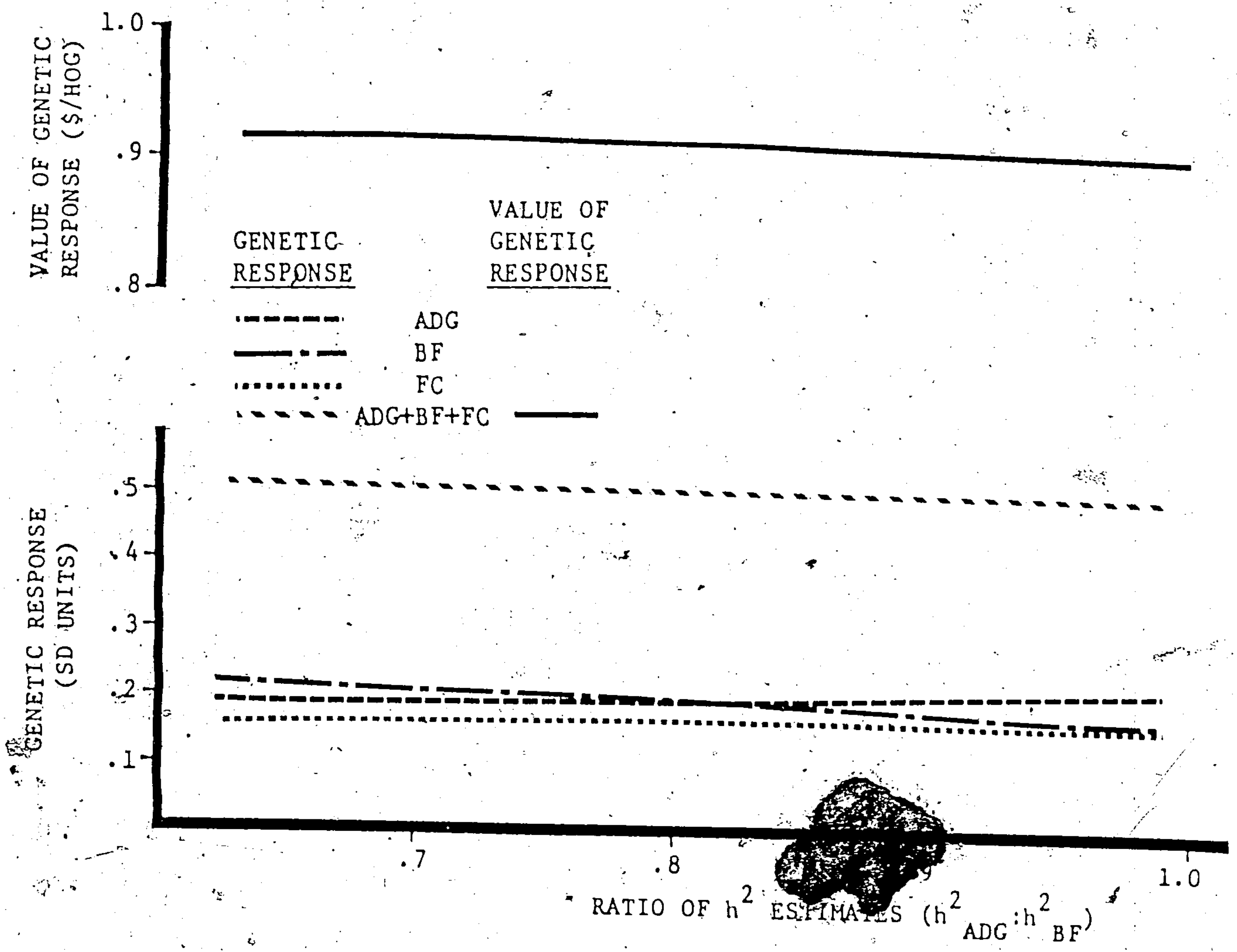

Fig. VIII-2. The effect of variation in the heritabilities of growth (ADG) and fat (BF) used in construction of the index on the resulting genetic responses, and the net economic value of those responses, when the ratio of the economic weights (ADG:BF) is 27:1 and genetic and phenotypic correlations are assumed to be zero.

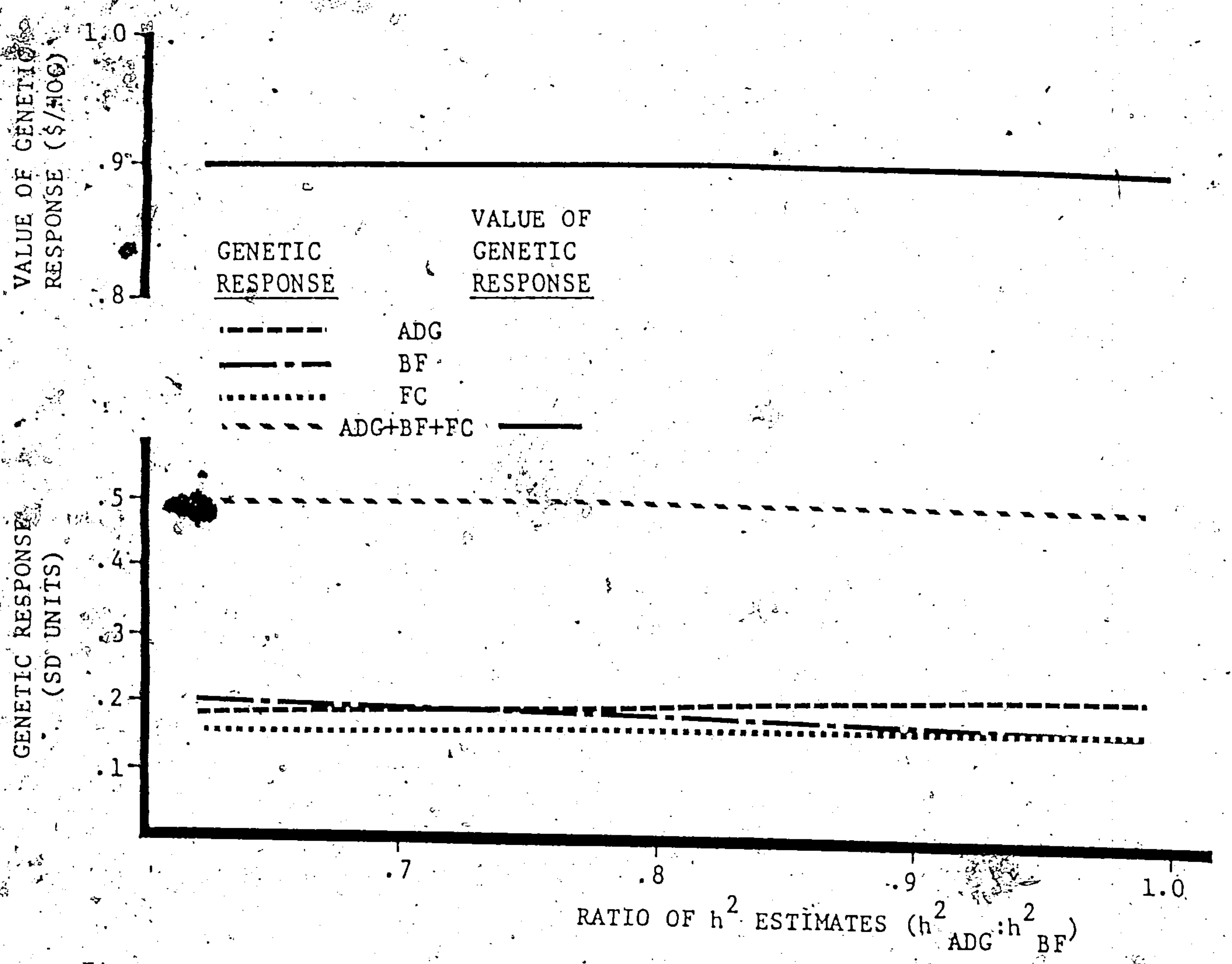

Fig. VIII-3. The effect on the genetic responses, and net economic value of those responses, resulting from index selection when heritabilities and economic weights are as given in Figure VIII-2 but the genetic and phenotypic correlations are assumed to be +0.25.

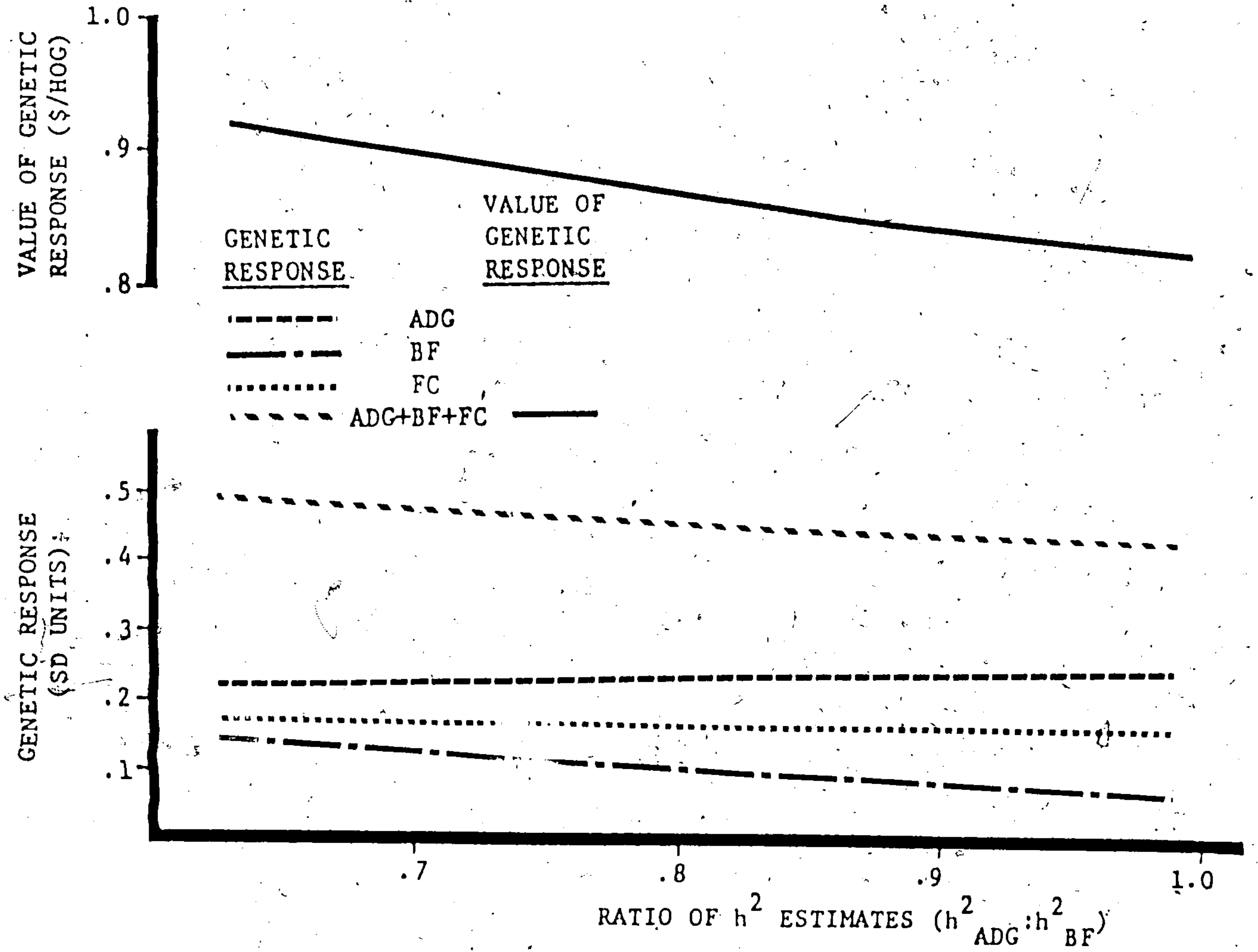

Fig. VIII-4. The effect on the genetic responses, and the net economic value of those responses, resulting from index selection when heritabilities vary in the manner of Figure VIII-2, genetic and phenotypic correlations are assumed to be zero and the ratio of economic weights (ADG:BF) is 50:1.

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IX. AN INVESTIGATION OF THE ROLE OF HALOTHANE TESTING IN THE CANADIAN SWINE ROP PROGRAM

Presently the Canadian swine ROP program routinely administers a halothane test to all boars entering central test stations. Boars showing a reaction to the halothane, and their full sibs, are culled. The program was implemented to reduce the incidence of halothane reactor pigs, and thus the gene(s) responsible for such reaction, with the ultimate goal of reducing the incidence of undesirable stress related problems believed to be associated with this condition.

Halothane exposure elicits responses collectively referred to as malignant hyperthermia (MH) in pigs susceptible to this drug (HP pigs). MH, which is characterized by an increased respiratory rate, increased concentrations of carbon dioxide in expired gas, profound respiratory and metabolic acidosis, blotchy cyanosis of the skin and rigidity of the musculature (van den Hende et al. 1976), can, in certain cases, result in death; thus the malignant aspect of the condition. Hyperthermia refers to an increase in body temperature which often accompanies MH although it is not universal (van den Hende et al. 1976).

A similar condition, referred to as the porcine stress syndrome (PSS), can be induced in certain pigs by exposure to extreme stress. Stressful situations such as mixing of strange pigs, transport, handling, abrupt changes in temperature and certain management practices may trigger this condition resulting in body temperature elevation, metabolic acidosis, muscle rigidity and sudden death (Mabry et al. 1981). Mitchell and Heffron (1980) note that the similarities between PSS and MH have led to the suggestion that they are identical conditions and differ only in the immediate causes of onset.

Stress is not only a principal factor involved in the onset of PSS, but it has also been fairly well established that exposure of pigs to stress prior to slaughter can result in undesirable meat quality characteristics of the carcass. Depending on the intensity and duration of the stress the carcass may exhibit either pale, soft, exudative (PSE) or dark, firm, dry (DFD) type meat. Pigs which exhibit PSE are characterized by the rapid accumulation of lactic acid in their muscles post mortem (Brooks and Cassens 1973). The resulting rapid pH drop leads to increased permeability of the muscle cells which allows water to enter freely into the extracellular fluid space and results in the development of PSE characteristics (Mitchell and Heffron 1980). As the muscles of pigs which have died as a result of MH brought on by drugs or natural stressors also exhibit a buildup of lactate and a rapid pH drop, it has been suggested that all three syndromes (MH, PSS, PSE) share a common etiology (Mitchell and Heffron 1980). This reasoning has led to the advocacy of halothane testing as a screening method to identify stress susceptible pigs and those likely to produce PSE meat (Eikelenboom et al. 1976; Bulla et al. 1979; McGloughlin et al. 1979; Webb 1980a).

While the links between MH, PSS, PSE and halothane sensitivity are far from being understood completely, what has been fairly well ascertained is that the incidence of halothane reactors can be rapidly changed in a population through selection. If one assumes the condition to be under the genetic control of a single recessive gene, as has been hypothesised by several researchers (Ollivier et al. 1975;

Minkema et al. 1976; Webb and Smith 1976; Ollivier et al. 1978), then HP (halothane positive) pigs would be homozygous for the recessive halothane gene and a single generation of selection for the condition should theoretically result in 100% incidence. On the other hand, if selection was against reactors, the rate at which they could be eliminated from the population, assuming Hardy-Weinberg equilibrium, could be determined from Falconer's (1981) equation expressing the change in gene frequency per generation when selection is applied against the homozygous recessive genotype and dominance is complete:

$$C_q = -sq^2 \ (1-q) \ / \ 1-sq^2$$

where:

C_q = change of gene frequency

s = intensity of selection against the homozygous recessive

q = initial frequency of the recessive allele

The rate of reduction of reactors would be dependent on both the frequency of the halothane gene and the intensity of selection against homozygous recessives (Fig. IX-1). Once the incidence of reactors dropped below about four per cent the rate of reduction would be very slow although this would still correspond to a gene frequency of 20%. To reduce an incidence of 4% by half would require at least 3 generations even under the most stringent culling procedures (i.e. at a selection intensity of 1, Table IX-1). With an intensity of selection of 0.25, fully 10 generations (approximately 25 years) of selection would be required to reduce a 4% incidence by half. In terms of halothane testing, an intensity of selection against reactors of 1 would correspond to a situation where all potential replacement breeding stock was halothane tested with all reactors culled. On the other hand, an intensity of selection of 0.25 would represent a situation where only half the replacement male breeding stock was tested with the same culling procedure as above. Clearly even this lower level of selection against reactors is not attainable by the ROP system which can test only about 4000 boars a year (2000 potential replacement based on culling pigs with performance indexes below 100).

Furthermore, it would be virtually impossible to eliminate the gene from a population because of its representation by an increasing proportion of heterozygotes, which cannot be detected by the standard halothane test, as the frequency of the gene was reduced. Therefore, to be effective, such a program would have to be expanded to test a much greater portion of the breeding population and would have to include test matings to detect heterozygotes.

Of course, elimination of reactors from a population would be an even slower process if halothane sensitivity was under the control of multiple genes. Reports in the literature of incomplete penetrance may indeed be indicative of such a situation. Ollivier et al. (1978) and Mabry et al. (1981) suggested that penetrance of the halothane gene was variable with estimates of penetrance of 0.50±0.24, 0.59±0.17, 0.69±0.23, 0.64±0.22, 0.82±0.29 and 1.30±0.65 in six pig populations reported in the former study.

The condition of the pig at the time of halothane testing can also play an important role in the identification of reactors. Minkema et al. (1976) reported that runt pigs, sick pigs and those which had undergone a period of starvation were liable to be misclassified as non-reactors (HN) although under normal circumstances they would show a reaction. This misclassification possibly occurred as a result of reduced body stores of glycogen which prevented the increased glycolytic rate and lactic acid production typical of MH.

The stress involved in administration of the halothane may itself affect the accuracy of the results. van den Hende et al. (1976) reported that the incidence of halothane induced MH in a population of Belgian Landrace pigs rested before administration of the drug was 42% while a similar group of pigs exercised for a short period prior to testing exhibited an incidence of 100%. Whether the latter group of pigs would have had as high an incidence had they been rested prior to testing is not known, but the results do not rule out the possibility that exposure to stress prior to testing (e.g. simple handling routines) altered the incidence of reactors.

Thus, it can be seen that there are many problems involved simply in identifying halothane reactors. The success of a halothane testing program, however, depends not only on the accurate identification of HP pigs, but also on the existence of a high correlation between halothane sensitivity and stress related problems. The literature reports of such correlations, though, are inconsistent. Mitchell and Heffron (1980) reported that 45% of the PSE carcasses in one study were produced by pigs which did not react to halothane. While it might be hypothesised that the PSE carcasses produced by the HN (halothane negative) pigs were produced by heterozygotes (therefore non-reactors) this is not supported by Jensen (1980) who reported very little difference in incidence of PSE between non-reactor homozygotes and heterozygotes (a difference in incidence of less than 1.5%). On the other hand, Jensen (1979), Webb and Jordan (1979) and Jensen (1980) reported the incidence of PSE among HP pigs to be only 61%, 74% and 32% respectively (Table IX-2). Thus, all halothane sensitive pigs do not produce PSE meat nor is all PSE meat produced only by halothane sensitive pigs. The variation in literature results is, in all probability, due to breed and management differences used in studying the problem. However, they do serve the purpose of illustrating the need to consider the population in question when examining links between halothane sensitivity and stress related problems.

Literature reports of the association between halothane sensitivity and carcass traits are also inconsistent (Table IX-3). However, these reports generally indicate that HP pigs tend to be leaner than HN pigs. This observation has created the concern that failure to take action against the halothane gene will permit its spread through the swine population as a result of a correlated response to selection for leanness. However, this concern must be viewed in respect of the population and the selection program in place and may have credence only when selection includes conformation traits. For example, the halothane gene has been shown to be associated with increased muscling (Ollivier 1975) and thus a selection program based primarily on conformation traits (i.e. heavy muscling) can be expected to result in an increase in the frequency of both HP pigs and meat quality problems. This is attested to by the Pietrain and Belgian Landrace breeds which both exhibit varying degrees of musclular hypertrophy and high incidences of halothane reactors and stress related problems. However, caution is required in assuming that muscular hypertrophy of itself is an indication of higher dissectable lean content. The results of a Bavarian (Grub) CPE (commercial product evaluation) test (in Fredeen 1981) reported that a breed cross which exhibited much lower per cent ham of carcass (about 4% less) compared to the Belgian Landrace did not differ significantly in dissected lean content.

The Canadian ROP program, however, does not include conformation traits in its selection program. Several studies which based selection on backfat or on an index similar to that employed by the ROP program which combined backfat and growth rate reported no correlated deterioration in meat quality with improvements in these traits (Hetzer and Miller 1973; Standal 1979; Sather et al. 1980). In a review of the literature by Fredeen (1975), there was no research evidence to support the claim that long term selection for reduced backfat would lead to meat quality problems. In the view of that author, meat quality problems were associated more with the degree of muscling (i.e. muscular hypertrophy) than the level of backfat carried by a pig. Kersey DeNise et al. (1983) reported that although selection based on per cent lean cuts and weight of lean cuts resulted in trends towards paler and softer pork these changes were small and insignificant. At the same time, however, moisture holding capacity and postmortem pH increased, indicative of an improvement in meat quality. While reports by Froystein et al. (1979) and Gerwig et al. (1979) did indicate that selection for reduced backfat and increased growth rate resulted in higher incidences of PSE type meat, the deterioration in meat quality in the former study was not accompanied by any change in the incidence of halothane reactors. In fact an unselected control line exhibited an incidence of HP pigs of 5% while there were no reactors in the selected line. Thus, literature reports generally indicate that concerns of increasing incidence of halothane reactors and deteriorating meat quality as a result of selection for leanness are unfounded.

The inclusion of growth rate in the ROP index should further serve to allay fears of the spread of the halothane gene through the Canadian pig population. Several studies report that HP pigs exhibited either reduced rates of growth under ad lib. conditions or no significant differences in growth rate compared to HN pigs (Table IX-4). Therefore, at the very least, selection based on an index which includes a measure of growth rate would not encourage the selection of halothane reactors.

In conclusion, it would appear that a halothane screening program as is employed presently by the Canadian ROP swine testing program will have very little impact on reducing either the incidence of reactor pigs in the Canadian swine herd or the incidence of stress related problems. To effectively reduce the incidence of halothane sensitive pigs the program would have to be expanded to include a much larger portion of the breeding population than just station tested boars and would have to include progeny tests or test matings to detect heterozygote carriers which do not react to the gas. Even if this were feasible, the impact such a program would have on reducing stress related problems is questionable. A more effective approach at present would seem to be to alter management and slaughtering techniques to reduce stress to a minimal level before seeking a genetic solution to a problem which may be largely managerial in origin. Since stressful situations such as loading, transport, delivery and slaughter have all been linked to subsequent meat quality problems (Froystein 1980; Kallweit 1980; Nielsen 1980; Carr 1985) it would seem logical that by concentrating efforts on improving handling, management and slaughter techniques the industry could benefit by reducing the stress placed on all pigs rather than by trying to identify and eliminate just the "stress susceptible" animals. This type of approach would be especially advantageous in a situation where the incidence of reactors is low and a small portion of the stress related problems would be solved by eliminating halothane reactors.

Trends in consumer preferences for pork products clearly indicate that the industry must persevere in its quest for reduced backfat. Simple economic considerations dictate that this quest must be pursued in the context of efficiency of lean meat production but in this process care must be taken to avoid any compromising of meat quality. The best evidence currently available indicates that this can be accomplished by avoiding the inclusion of those conformation characteristics in a selection program which appear to be associated with stress related problems and by giving adequate emphasis to growth rate. Obviously, however, further study is required to determine more clearly the relationships between halothane sensitive animals and stress problems in the Canadian hog population. At the same time, since several beneficial traits have been associated with the halothane gene (e.g. higher killing out percentage, improved muscling attributes of the ham and loin, Table IX-3) the industry might benefit more in the long term by developing mating systems to exploit some of these benefits rather than trying to eliminate the gene, or genes, from the population. Two possibilities might be either to develop specialized sire and dam lines with different alleles fixed in the lines, as suggested by Smith (1980), or to try to separate the beneficial effects of the halothane gene on carcass traits from the harmful effects on other traits as suggested by Webb (1980b). There are, of course, difficulties associated with both schemes but the swine industry might find it worthwhile to investigate the feasibility of such programs as applies to Canadian conditions.

Table IX-1. Generations required to reduce incidence of HP boars under two intensities of selection(s)

INCIDENCE	s = 1.0	s = 0.25
4% → 2%	3 gen.	10 gen.
2% → 1%	3 "	14 "
1% → 0.5%	5 "	19 "

Table IX-2. Incidence of PSE among HP and HN pigs

HP	HN	REFERENCE	BREED
31.7%	10.2%	Webb & Jordan, 1979	Pietrain x Hampshire
61.1%	22.3%	Jensen, 1979	Danish Landrace
73.8%	22.7%	Jensen, 1980	" "

Table IX-3. Summary of carcass trait differences between HP and HN pigs[+]

TRAIT	MEAN[‡]	MIN	MAX	NO. STUDIES
% Lean	2.9	1.9	4.6	6
% Ham	0.6	0.2	1.0	6
% Loin	0.3	-0.1	0.5	3
Ave. Backfat (mm)	-1.0	-4.0	1.0	13
Killing Out %	1.0	0.2	2.6	6
Eye Muscle Area (cm^2)	1.0	-2.7	3.4	6

[+] from Webb, 1980b

[‡] HP-HN

Table IX-4. Differences in ADG (gm/day) between HP and HN pigs fed ad libitum

HP-HN	SIG.	REFERENCE	BREED
-54	*	Jensen, 1980	Danish Landrace
0	NS	Carlson et al., 1980	Yorkshire x Poland China
-11	NS	Ollivier et al., 1978	Pietrain
-19	*	" " " "	"
-45	*	Eikelenboom et al., 1976	Dutch Landrace
-137	**	Verstegen et al., 1976	" "

* P<0.05
** P<0.01
NS = not significantly different (P>0.05)

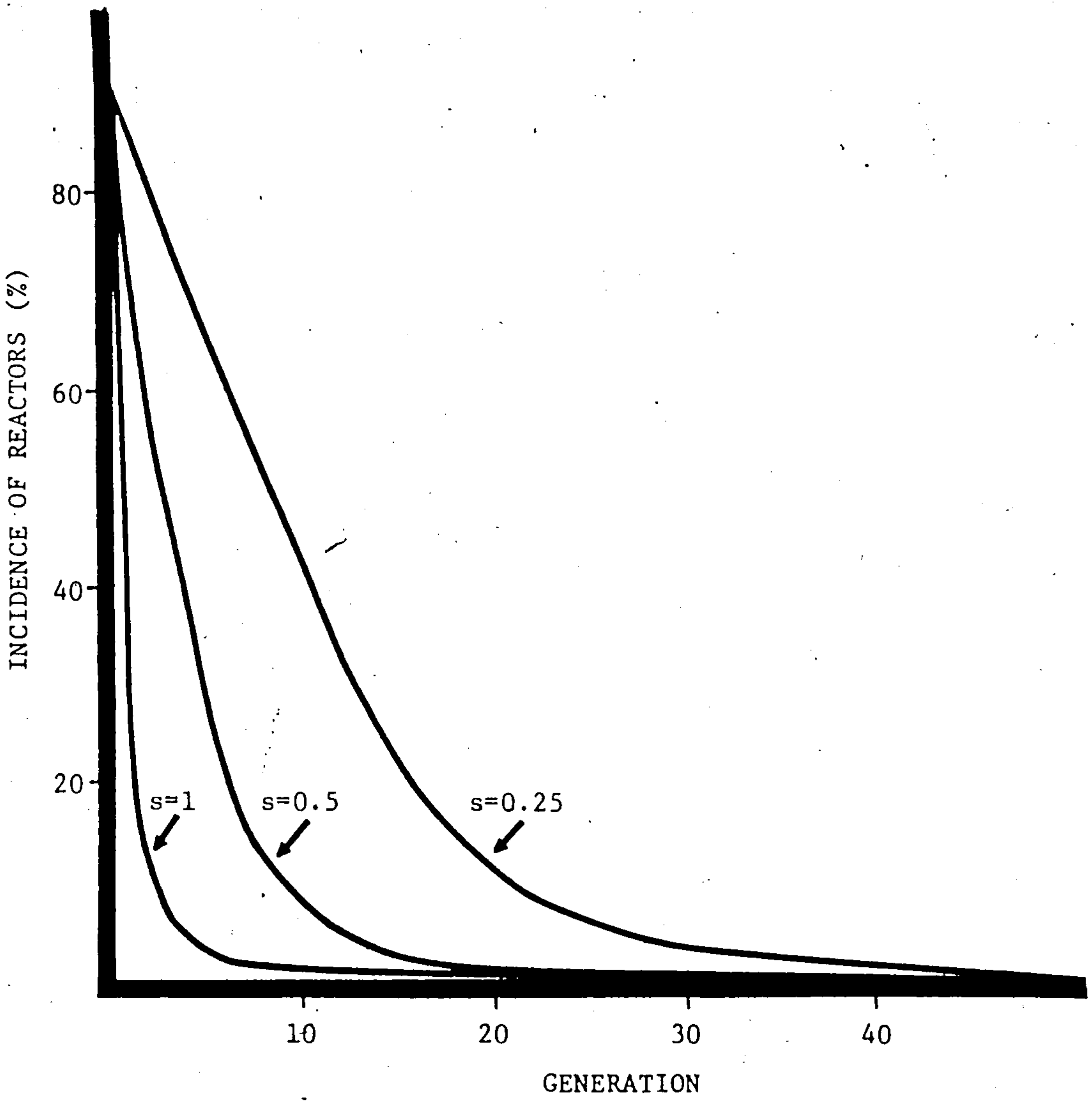

Fig. IX-1. The rate of reduction of the incidence of halothane reactors at various intensities of selection (s) against reactors.

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X. GENERAL SUMMARY

Unbiased genetic comparisons between boars submitted to central ROP test stations are possible only if all comparisons are made under standard conditions. However, the results reported in the preceding chapters indicated that there are nongenetic factors inherent in the system which may affect the ranking of boars on the basis of test results.

Significant differences between fill periods within a station indicated that the use of "strict" contemporary groups for use in index construction would be preferable to a rolling average. Although rolling averages are deemed necessary as a means of compensating for low numbers within fill periods, such a practice could assign above or below average index values to entire fills of boars as a result of temporary environmental effects. Thus, in the Yorkshire breed especially, a strict contemporary average should be incorporated into the index. Such a move would not alter the ranking of boars within a fill but would alter their index values. Only those breeds with low numbers within a fill should continue to rely on rolling averages.

Although the limitations of ROP data in examining the effects of the pretest environment must be acknowledged, the studies reported in Chapter V do not rule out the possibility of a carry-over effect of the pretest environment with heavier boars at delivery exhibiting trends towards superior growth rate and feed conversion on test.

The role of the "warm-up" period needs to be further investigated but the observation of superior growth rates during this period of boars with lower rates of growth at delivery suggests some type of compensatory gain. Without an adequate "warm-up" period it is conceivable that this compensatory gain would be exhibited during the test period and could thus affect the interpretation of test results. For this reason it is essential that the test be modified to provide an adjustment period to all boars subsequent to submission to the test stations. One way in which this could be accomplished would be by raising the weight of test commencement while maintaining entry weights at the present range.

Chapters VI and VII indicated that there were definite biases associated with the present backfat adjustment procedure. Over a narrow terminal weight range these biases were negligible but became substantial at the extreme ends of the "acceptable" terminal weight range. The advantage that the adjustment procedure bestowed upon the heavier boars at test termination in terms of adjusted backfat depth would result in such factors as initial weight and differential growth rates of penmates essentially becoming important factors in determining a boar's apparent test performance. Those boars, or pens, with relatively high initial weights would have a better chance of completing test at or above 90 kg and would therefore avoid being adjusted upwards while boars with high rates of growth relative to their penmates which are removed from test at weights greater than 90 kg would be adjusted downwards. Thus, even two boars with the same genetic potential for backfat deposition could be judged to be genetically different by virtue of the adjustment procedure.

The solution to the problem of biased adjustment procedures is to remove all boars from test at a standard weight rather than basing termination on a pen average. Certain boars with low rates of growth would still be terminated at weights less than 90 kg and, without changes being made to the testing procedure, would have to be adjusted upwards. However, more thorough investigation of backfat deposition rates would yield adjustment procedures which would insure that any biases inflicted by adjustment were kept to a minimum.

A phenotypic index appeared to do an effective job of combining average daily gain and adjusted backfat depth into a single index value at the completion of test. Compared to an index which also included genetic and economic parameter estimates, the loss in expected genetic gain was negligible. The dynamic aspect of the phenotyic index, its ease of practical application and the problems associated with accurate estimation of genetic and economic parameters for inclusion in a genetic index make the phenotypic index a preferable choice of a selection index.

It was concluded in Chapter IX that the inclusion of halothane testing in the ROP program will not provide an effective means of either preventing, or reducing, stress related problems in Canadian pigs. The low incidence of halothane susceptible pigs in the national pig herd would make eradication of this condition impossible even under the simplest of genetic models. Halothane susceptibility appears to be associated with certain beneficial characteristics and thus the industry could benefit more in the long term by investigating methods of exploiting these beneficial characteristics rather than trying to eliminate the gene from the population.

Although the preceding studies indicated that there are nongenetic factors inherent in the ROP testing program which may result in misinterpretation of the the test results, it would seem that most of these problems could be overcome by minor changes to the present testing procedures. A much more complex problem, however, is to insure that the test results are utilized in a manner which will lead to the overall genetic improvement of the national pig herd. The present structuring of the seedstock industry and the limited amount of test station space available for accurate between-herd comparisons makes it doubtful that the system is actually capable of sustained genetic improvement. This, coupled with recent reports of a general lack of application of test results in selection decisions by purebred breeders enrolled in the ROP program (Fredeen 1985) makes questionable the wisdom of attempting to improve the test procedures already in place. The swine industry as a whole would be best served by either restructuring the testing program to ensure that test results were properly applied to selection decisions or by disbanding the program and putting the onus on the breeders themselves for the implementation of programs to ensure genetic improvement.

The former option carries with it overtones of increased supervision and government control which would be required to insure that the program was not abused. The second option, however, would free the government of its supervisory role and allow it to divert the monies presently spent on testing into research. Ideally, the government should lead the way in breeding research with the industry having the responsibility of implementing and applying the results.

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APPENDIX

Class means of the delivery variables INWT, PGTH, WTVR, GRVR, WTDV, DIST and FILL

Appendix Table 1. Means (with standard errors in parenthesis) of the performance traits, expressed as deviations from the contemporary group averages, and FNWT of the INWT classes

TRAIT	STATION-BREED SUBCLASS	CLASS 1	2	3	4	5	6
ADG	YONT	-0.036 (0.020)	-0.001 (0.012)	-0.009 (0.008)	-0.001 (0.012)	0.008 (0.009)	0.022 (0.012)
	LONT	-0.016 (0.010)	0.001 (0.011)	0.000 (0.008)	0.003 (0.010)	0.011 (0.010)	-0.002 (0.017)
	YLED	-0.008 (0.010)	-0.019 (0.010)	0.001 (0.009)	-0.010 (0.008)	0.008 (0.009)	0.036 (0.011)
FC	YONT	0.025 (0.028)	0.028 (0.025)	0.034 (0.016)	0.001 (0.014)	-0.035 (0.017)	-0.045 (0.019)
	LONT	0.003 (0.027)	0.026 (0.021)	-0.006 (0.018)	0.000 (0.023)	-0.001 (0.029)	-0.017 (0.031)
	YLED	0.029 (0.016)	0.007 (0.016)	0.009 (0.018)	-0.008 (0.016)	-0.015 (0.016)	-0.038 (0.018)
ABF	YONT	-0.054 (0.268)	-0.180 (0.314)	0.120 (0.168)	0.054 (0.238)	-0.122 (0.305)	0.029 (0.269)
	LONT	-0.048 (0.230)	0.357 (0.299)	-0.050 (0.198)	-0.150 (0.250)	0.078 (0.316)	-0.046 (0.372)
	YLED	0.261 (0.247)	-0.520 (0.245)	0.161 (0.271)	-0.371 (0.310)	0.160 (0.278)	0.316 (0.279)
INDEX	YONT	-5.7 (3.8)	-1.7 (3.0)	-3.5 (1.8)	-0.3 (2.1)	3.9 (1.9)	4.9 (2.6)
	LONT	-5.1 (3.0)	-2.1 (3.3)	2.0 (2.2)	1.2 (2.5)	1.6 (2.9)	-2.3 (4.5)
	YLED	-4.7 (3.1)	-2.2 (2.7)	0.2 (2.7)	0.9 (2.8)	-0.1 (2.2)	7.0 (2.8)
FNWT	YONT	83.3 (1.0)	86.5 (0.7)	88.1 (0.4)	89.1 (0.5)	90.1 (0.4)	90.3 (0.4)
	LONT	86.8 (0.7)	88.4 (0.8)	88.9 (0.4)	89.4 (0.4)	90.2 (0.5)	89.8 (0.8)
	YLED	88.1 (0.5)	89.0 (0.4)	89.8 (0.4)	91.3 (0.4)	90.3 (0.3)	90. (0.4)
n	YONT	20	31	80	64	63	44
	LONT	35	35	90	54	40	29
	YLED	69	69	70	49	58	49

Appendix Table 2. Means (with standard errors in parenthesis) of the performance traits, expressed as deviations from the contemporary group averages, of the PGTH classes

TRAIT	STATION-BREED SUBCLASS	CLASS					
		1	2	3	4	5	6
ADG	YONT	-0.003 (0.018)	0.026 (0.012)	0.002 (0.011)	-0.010 (0.008)	-0.010 (0.011)	0.015 (0.011)
	LONT	-0.010 (0.013)	0.014 (0.010)	-0.007 (0.009)	0.004 (0.009)	-0.007 (0.010)	0.001 (0.015)
	YLED	-0.020 (0.011)	-0.007 (0.013)	-0.007 (0.008)	0.017 (0.008)	0.004 (0.009)	0.000 (0.012)
FC	YONT	0.002 (0.028)	0.010 (0.025)	0.020 (0.015)	0.001 (0.016)	-0.008 (0.017)	-0.035 (0.020)
	LONT	0.010 (0.038)	-0.027 (0.021)	0.009 (0.018)	-0.021 (0.018)	0.021 (0.027)	0.029 (0.032)
	YLED	0.041 (0.024)	0.010 (0.020)	-0.002 (0.013)	-0.025 (0.014)	0.001 (0.014)	0.005 (0.023)
ABF	YONT	0.36 (0.31)	0.55 (0.35)	0.08 (0.19)	-0.11 (0.17)	-0.32 (0.20)	0.04 (0.31)
	LONT	-0.24 (0.27)	0.23 (0.25)	0.15 (0.25)	0.02 (0.22)	-0.50 (0.26)	0.26 (0.33)
	YLED	0.03 (0.32)	-0.08 (0.31)	-0.28 (0.22)	0.18 (0.22)	-0.09 (0.28)	0.42 (0.36)
INDEX	YONT	-2.9 (4.2)	-0.3 (3.0)	-1.3 (1.9)	-0.4 (1.7)	0.4 (2.2)	4.9 (2.6)
	LONT	-0.6 (3.5)	0.5 (2.9)	-1.6 (2.1)	3.8 (2.2)	0.6 (3.0)	-5.5 (4.5)
	YLED	-5.3 (3.2)	-4.5 (3.3)	0.7 (2.2)	3.0 (2.4)	-0.9 (2.4)	5.7 (3.6)
n	YONT	16	31	74	75	69	37
	LONT	23	48	56	71	49	36
	YLED	43	47	87	90	58	39

Appendix Table 3. Means (with standard errors in parenthesis) of the performance traits, expressed as deviations from the contemporary group averages, of the WTVR classes

TRAIT	STATION-BREED SUBCLASS	CLASS 1	2	3	4	5	6
ADG	YONT	0.000 (0.008)	0.002 (0.010)	-0.012 (0.010)	0.015 (0.014)	0.012 (0.016)	-0.025 (0.026)
	LONT	0.000 (0.006)	-0.008 (0.010)	0.001 (0.011)	0.009 (0.018)	0.003 (0.017)	0.014 (0.014)
	YLED	-0.003 (0.007)	-0.006 (0.009)	0.004 (0.009)	0.000 (0.011)	-0.003 (0.015)	0.026 (0.015)
FC	YONT	-0.013 (0.012)	0.003 (0.016)	0.019 (0.022)	0.004 (0.028)	-0.009 (0.026)	0.055 (0.029)
	LONT	-0.011 (0.014)	0.020 (0.024)	-0.003 (0.024)	0.015 (0.036)	0.007 (0.041)	0.003 (0.047)
	YLED	-0.003 (0.012)	0.002 (0.013)	-0.009 (0.016)	-0.006 (0.022)	0.013 (0.027)	0.021 (0.027)
ABF	YONT	-0.09 (0.14)	-0.17 (0.23)	0.04 (0.24)	0.24 (0.34)	0.28 (0.25)	0.57 (0.48)
	LONT	0.05 (0.16)	-0.27 (0.25)	0.05 (0.30)	-0.40 (0.24)	0.15 (0.41)	1.16 (0.55)
	YLED	0.03 (0.16)	0.16 (0.26)	-0.29 (0.28)	-0.04 (0.41)	-0.27 (0.33)	0.28 (0.51)
INDEX	YONT	0.9 (1.4)	0.8 (2.2)	-2.7 (2.5)	1.8 (3.0)	0.6 (3.3)	-9.1 (3.2)
	LONT	-1.0 (1.7)	-0.3 (2.9)	1.6 (3.1)	8.3 (4.2)	0.5 (4.5)	-3.7 (3.1)
	YLED	-1.6 (1.7)	-1.0 (2.5)	3.4 (2.8)	5.3 (3.3)	-4.4 (3.8)	5.6 (4.7)
n	YONT	125	70	41	27	26	13
	LONT	128	59	44	19	23	10
	YLED	142	81	54	32	29	26

Appendix Table 4. Means (with standard errors in parenthesis) of the performance traits, expressed as deviations from the contemporary group averages, of the GRVR classes

	STATION-BREED	CLASS					
TRAIT	SUBCLASS	1	2	3	4	5	6
ADG	YONT	0.014 (0.009)	-0.007 (0.011)	-0.012 (0.012)	-0.012 (0.011)	0.015 (0.013)	0.000 (0.013)
	LONT	0.004 (0.007)	-0.013 (0.011)	0.000 (0.010)	0.000 (0.011)	0.002 (0.019)	0.006 (0.012)
	YLED	0.015 (0.010)	-0.011 (0.008)	-0.005 (0.010)	-0.008 (0.010)	0.007 (0.013)	0.007 (0.009)
FC	YONT	-0.016 (0.016)	-0.016 (0.015)	0.031 (0.021)	0.002 (0.022)	0.014 (0.028)	0.006 (0.020)
	LONT	-0.006 (0.016)	-0.011 (0.023)	0.013 (0.023)	-0.004 (0.034)	0.023 (0.035)	0.002 (0.029)
	YLED	0.007 (0.017)	-0.013 (0.013)	-0.008 (0.016)	-0.001 (0.018)	0.005 (0.032)	0.016 (0.016)
ABF	YONT	0.20 (0.18)	-0.39 (0.20)	-0.06 (0.25)	-0.15 (0.28)	0.06 (0.35)	0.40 (0.21)
	LONT	0.14 (0.18)	-0.08 (0.26)	-0.29 (0.28)	-0.23 (0.36)	0.09 (0.32)	0.28 (0.30)
	YLED	0.16 (0.22)	-0.05 (0.22)	-0.03 (0.28)	-0.17 (0.31)	-0.18 (0149)	0.11 (0.27)
INDEX	YONT	1.6 (1.8)	1.6 (2.0)	-3.4 (2.5)	-0.7 (2.9)	2.3 (3.1)	-2.5 (2.2)
	LONT	-0.4 (2.0)	-3.0 (2.8)	0.3 (3.1)	3.4 (4.0)	6.1 (4.4)	-0.3 (2.8)
	YLED	-0.9 (2.6)	-1.4 (2.1)	-0.2 (2.8)	1.7 (3.0)	7.5 (4.9)	0.2 (2.6)
n	YONT	78	70	50	33	25	46
	LONT	92	49	47	34	23	38
	YLED	67	90	64	47	25	71

Appendix Table 5. Means (with standard errors in parenthesis) of the performance traits, expressed as deviations from the contemporary group averages, of the WTDV classes

TRAIT	STATION-BREED SUBCLASS	CLASS					
		1	2	3	4	5	6
ADG	YONT	-0.009 (0.015)	-0.021 (0.010)	0.000 (0.006)	0.002 (0.009)	0.019 (0.012)	0.008 (0.017)
	LONT	-0.013 (0.014)	-0.001 (0.012)	-0.006 (0.006)	0.003 (0.008)	0.008 (0.012)	0.026 (0.015)
	YLED	-0.007 (0.013)	-0.016 (0.010)	-0.007 (0.006)	0.001 (0.007)	0.021 (0.008)	0.029 (0.012)
ABF	YONT	0.57 (0.28)	-0.02 (0.20)	-0.04 (0.14)	-0.22 (0.16)	0.27 (0.28)	0.17 (0.32)
	LONT	0.48 (0.42)	-0.25 (0.22)	0.04 (0.14)	-0.20 (0.17)	0.07 (0.30)	0.44 (0.37)
	YLED	-0.31 (0.38)	-0.10 (0.28)	0.16 (0.15)	-0.04 (0.19)	-0.29 (0.27)	0.29 (0.35)
INDEX	YONT	-4.7 (2.7)	-2.9 (1.9)	0.6 (1.1)	1.2 (1.4)	1.3 (2.3)	-0.7 (2.9)
	LONT	-2.9 (2.9)	2.0 (1.6)	-1.3 (1.1)	0.4 (1.6)	2.7 (2.0)	1.2 (3.1)
	YLED	0.2 (1.8)	0.7 (1.4)	-1.5 (1.1)	-0.3 (1.3)	4.2 (1.6)	0.4 (2.7)
n	YONT	39	68	231	159	68	39
	LONT	33	63	229	145	63	33
	YLED	55	86	269	177	86	55

Appendix Table 6. Means (with standard errors in parenthesis) of INWT and FILL for the DIST classes in the YONT and YLED subclasses

	YONT			YLED		
CLASS	n	INWT	FILL	n	INWT	FILL
	64	26.1 (0.3)	4.9 (0.4)	67	24.4 (0.4)	5.1 (0.5)
2	45	25.1 (0.4)	4.5 (0.5)	24	25.1 (0.7)	5.0 (0.7)
3	23	26.4 (0.5)	4.9 (0.8)	163	25.3 (0.3)	6.5 (0.3)
4	77	26.0 (0.3)	4.5 (0.4)	110	23.4 (0.3)	7.6 (0.3)
5	10	22.9 (1.0)	5.6 (0.9)			
6	58	26.0 (0.4)	5.1 (0.4)			
7	25	24.6 (0.6)	6.6 (0.6)			

Appendix Table 7. Means (with standard errors in parenthesis) of FNWT of the FILL classes

	YONT		LONT		YLED	
CLASS	n	FNWT	n	FNWT	n	FNWT
1	64	89.7 (0.5)	63	89.2 (0.4)	52	90.5 (0.4)
2	35	90.1 (0.6)	34	88.8 (0.7)	28	90.8 (0.5)
3	36	88.7 (0.7)	29	90.1 (0.7)	7	89.1 (1.1)
4	16	89.6 (1.2)	26	89.5 (0.7)	41	90.2 (0.4)
5	30	88.1 (0.7)	16	88.1 (1.1)	25	89.9 (0.7)
6	10	88.4 (1.0)	5	87.6 (2.4)	30	90.6 (0.5)
7	22	88.2 (1.0)	14	88.9 (1.1)	43	89.2 (1.4)
8	21	87.3 (0.8)	30	89.1 (0.7)	30	90.0 (0.7)
9	40	86.9 (0.6)	26	88.3 (0.6)	23	89.1 (0.7)
10	17	86.5 (0.9)	29	88.0 (0.9)	24	89.8 (0.7)
11	9	88.9 (1.2)	2	87.5 (0.5)	19	89.5 (0.5)
12	2	89.3 (1.2)	9	88.8 (1.5)	21	87.9 (0.8)
13					2	86.8 (4.7)
14					6	86.8 (1.3)
15					12	88.3 (1.2)
16					1	89.8 (0.0)

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Unrefereed Journals:

Allan, B.B. and Fredeen, H.T. The choice of a selection index for swine. 1983. 62nd Annual Feeders' Day Report, Department of Animal Science, University of Alberta. p 144.

Presentations:

Allan, B.B., Fredeen, H.T. and Weiss, G.M. 1983. Comparison of two types of selection indexes for swine. Presented at the annual meeting of the Canadian Society of Animal Science held at The Nova Scotia Agricultural College, Truro, N.S., July, 1983. (abstract in Can. J. Anim. Sci. 63:1023).

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