SOME ASPECTS OF GROWTH RATE AS IT IS RELATED TO REPRODUCTIVE EFFICIENCY IN DAIRY CATTLE

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ABSTRACT

The purpose of the study reported in this thesis was to evaluate whether liveweight, measured in Friesian yearlings immediately before the breeding season commenced and in parous cows of the same breed just before calving for the herd began, was related to reproductive performance during the first four weeks of the mating period. Should such a relationship be confirmed 'target weights' which would ensure a high level of reproductive efficiency could be established for animals of this breed under normal husbandry conditions in New Zealand. A pre-requisite to the investigation was that the method(s) used should be easily applied in a commercial farming situation.

Body weight measurements for 184 yearlings (5 herds) and 288 parous cows (4 herds) which were at least three-quarter bred Friesian were taken at the times indicated above and related to submission rates (S.R.) and pregnancy rates (P.R.) during the first four weeks of the following breeding season. The cows were bred by artificial insemination with heat checks being made by experienced stock men; yearlings were mated to young bulls fitted with chin ball mating harnesses. P.R. and the dates of conception were confirmed by both pregnancy examinations at the conclusion of the breeding period and by subsequent calving information.

Reproductive performance in the yearling heifers was high with S.R. averaging 94% (range 88-100%) and P.R. 86% (range 71-100%) for the five herds. The majority of the heifers were judged to be in good body condition with mean body weights for the herds ranging between 231 ± 27 and 277 ± 22 kg (mean $\pm$ S.D.). Differences in liveweight between herds were probably related to management during rearing although age variation and minor differences in the amount of Friesian 'blood' in each herd could have been contributing factors.

When individual herd effects were removed a positive but non-significant linear relationship between liveweight and S.R. was achieved with the yearlings. From the six points plotted on the regression it was noted that the lightest group of animals had a submission rate of 76%

whereas all other groups had submission rates in excess of 94% thus suggesting a threshold effect. The minimum liveweights for the lightest yearling groups exceeding a 90% submission rate varied from 204-229 kg depending on the herd.

While a positive relationship between liveweight and pregnancy rate was noted in the yearling data this was neither linear nor significant - further investigations seem warranted to resolve this particular issue because of its importance in breeding management. The significant differences noted between herds in yearling pregnancy rates may have been due to differences in fertility of the bulls used.

The reproductive performance of the three year-old and mature age groups of parous cows was satisfactory (S.R. averaged 87 and 86% and P.R. 69 and 65% respectively) but that of the two year-old cattle poor (S.R. 67% and P.R. 56%). Marked differences occurred between herds. Apart from the possible influence of liveweight before calving on these parameters of performance analysis of the reasons for herd differences was beyond the scope of this study and not attempted.

Differences in liveweight of the different age groups of cows both within and between herds was marked and, apart from the relationship with age, could most likely be attributed to management during the late autumn and winter period before calving began. Any association between liveweight and subsequent reproductive performance was however generally poor and inconsistent and in retrospect it was concluded that the method that had been used for investigating any possible relationship was unsatisfactory. A future investigation in which variables are more effectively controlled has been suggested.

Two year-old heifers experiencing their first lactation continue to be a problem group particularly under New Zealand dairy husbandry conditions. Careful management commencing during rearing and extending through first mating, calving and second breeding is required if a high level of reproductive efficiency in this age group is to be achieved.

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INTRODUCTION

A concentrated calving period is a unique feature of the seasonal pattern of dairy farming in New Zealand. It is timed to co-incide with the spring flush in pasture growth so as to achieve maximum milk production at lowest cost; in addition this practice simplifies management with respect to cows at different stages of their annual reproductive and milking cycle as well as reducing problems associated with calf rearing.

High breeding efficiency of dairy cattle in New Zealand is thus associated with a short concentrated period of mating usually of about nine weeks duration. To achieve the objective of high in calf rates during this short period of time requires that as many animals as possible in the herd be bred during the first four weeks after mating commences (i.e. a high submission rate) and that satisfactory pregnancy rates be obtained at each breeding.

Many factors can affect submission rate and among these lack of cyclical activity associated with an inadequate level of nutrition appears to be important in many dairy herds in this country. Evidence indicates that this problem is more frequent, and of greater magnitude, in younger lactating animals while 'silent heat' and/ or failure to recognise overt oestrus, in addition to lack of cyclical activity, contribute significantly to the submission rate problem in older animals in the herd (Fielden, 1976; Fielden *et al.*, 1976). Furthermore, following a study of planned animal health schemes applied to dairy herds, Moller (cited by Fielden *et al.*, 1976) has pointed out that there appears to be a positive relationship between body weight and submission rate of dairy animals under New Zealand farming conditions.

There is little doubt that under feeding of cattle can occur under an all grass grazing farming system. Pasture for example varies considerably in both yield and quality with changes in seasons. An over-estimate of the feeding value of forage, or of the feed intake under self feeding conditions, can thus readily contribute to an underfeeding problem and, in addition, variations in the seasonal pasture growth pattern can seriously alter the food supply that is available at any given time.

Since in dairy cattle, submission rate is mainly a problem of animals returning to post-partum cyclical activity, and because plane of nutrition is a variable which can be readily manipulated, the concept of a target weight for animals at calving, which would correlate with subsequent reproductive and productive performance, could be a useful guide in management. Such a concept, if practicable, is particularly important since no immediate or even short term method of beneficially affecting cyclical activity has yet been described for animals which are in a 'poor' reproductive state. Nor does a short term boost in food intake overcome the problem. Similarly, a target weight for yearlings at mating is desirable in view of the fact that onset of puberty is more a function of liveweight than age.

The objective of the study reported in this thesis was to evaluate the relationship between submission and pregnancy rates with that of body weights of Friesian yearlings prior to mating, and of Friesian cows before calving, in an effort to establish an optimum target liveweight for efficient reproduction. An important consideration in respect to the plan of the investigation was that, whatever technique was adopted in order to establish the relationship, it had to be 'practical' in application from the commercial dairy farmers point of view.

LITERATURE REVIEW

REPRODUCTIVE EFFICIENCY AND PARAMETERS USED IN ITS ASSESSMENT

It is hardly necessary to stress the economic importance of reproductive efficiency for it is obvious that the aim of dairy farming is to achieve a calving rate of one calf per cow per year and so to renew milk production initiated through parturition.

Reproductive efficiency is largely dependent upon a satisfactory level of herd fertility which in turn is affected by both genetic and environmental factors. To be reproductively efficient, an animal must be able to both conceive and produce a viable offspring at a calving interval of about 12 months. Factors associated with this are breeding at an early age, high submission rates, high conception rates during the breeding period and low postnatal losses.

Major measures which are used for the assessment of reproductive efficiency include:

i. Calving Interval

This represents the interval from one calving to the next and is almost always presented on a herd basis. It has been shown that a 12-13 month calving interval yields the highest milk production during the lifetime of a cow (Hartigen, 1972). In a recent report the Milk Marketing Board (1975) indicated that a 365-day calving interval gave the maximum 305-day milk yields while production was depressed where calving intervals were longer or shorter than 365 days.

In actual practice, most studies indicate that the usual figure for calving intervals is nearer to 395 days though exceptions are noted in seasonal supply dairy herds in both New Zealand and Ireland where calving intervals of 364 and 363 days respectively have been reported (Shrestha, 1978).

Calving interval is the most important parameter describing reproductive efficiency and it is mainly influenced by the time from calving to conception i.e. days open.

ii. Days Open

This is the calving to conception interval. It offers a meaningful analysis of the reproductive condition of a herd and of individual cows within that herd (Lineweaver and Spessard, 1975). It is highly correlated with calving interval but it does not take account of losses which may occur during a pregnancy after the estimate has been made.

Days open is made up of the calving to first service interval and the interval from first service to conception. The resumption of cyclical activity after parturition is a key factor affecting it. Other influences include management decisions as to when to begin first breeding, the efficiency of oestrus detection on the farm and the fertility level achieved once breeding has started.

iii. Services Per Conception

This is one of the primary measures used in evaluating reproductive performance and herds that require more than two services per conception are generally considered to be problem herds (Morrow *et al.*, 1966). As the number of services per conception is inversely related to the post-partum interval before breeding commences (Olds and Cooper, 1970; Britt, 1975), a herd with a low services per conception index may have a long intercalving interval, or *vice versa*. Thus calving interval is a more appropriate measure of breeding efficiency. A further difficulty encountered with using the parameter of services per conception is that of determining the exact time when conception has occurred.

iv. Non-Return Rate

This is a measure of 'conception rate' and its estimation is based on the percentage of animals bred that do not return for a further service within a specified period. This specified period varies from country to country. In New Zealand, a 49-day non-return rate is used as compared to 60-90 days in the United Kingdom and U.S.A (Pelissier, 1976). Though non-return rates are highly correlated with 'conception rates', as an estimate they are always higher (Spalding *et al.*, 1975; Pelissier, 1976) owing to such problems as post-service anoestrus in the absence of a conceptus and incomplete records of return to service (Macmillan *et al.*, 1977b).

Non-return rate has to be measured in relation to the post-partum period since the ability of a cow to conceive increases as the post-partum period before service lengthens. Additionally, non-return rate only measures cows which have been bred, and as an estimate of performance it should be judged in conjunction with the proportion of unbred cows in the herd in which the estimate is being made.

GROWTH RATE OF DAIRY YOUNG STOCK

Rearing of young dairy stock is carried out to provide herd replacements. A sound heifer replacement programme is aimed at keeping deaths to a minimum, successfully mating the stock at a desired age and rearing them at a level so that subsequent milk production and fertility are not prejudiced (Warner, 1970a; Davey, 1976).

Although the growth potential of an animal is limited by its genotype, the extent to which the animal expresses this potential is mainly determined by nutritional factors. Thus, it has been possible to control growth of heifers by manipulating their plane of nutrition (Swanson, 1967; Preston and Willis, 1974).

While there are a variety of growth standards for dairy heifers, heifers of different breeds cannot be bound to the same standard and even individuals within breeds may differ as much as 20-25% from an average growth pattern (Swanson, 1967).

It is important when considering the question of level of rearing to have some conception of normal or average rates of growth; a survey of liveweights at various stages of development of Jersey and Friesian cattle is illustrated in Table I.

It should be noted that the average age at first calving was 20-24 months for the Jerseys and 28-32 months for the Friesians in the data cited in this table.

Early breeding of cattle has economic advantages since it shortens the unproductive period of the animal's life and at the same time increases its life time production provided it does not decrease longevity. There appears nothing to gain from a production point of view in growing calves or heifers too fast (Burt, 1956; Lamond and

Campbell,1968; Warner, 1970b). For Jersey and Friesian breeds, from birth to weaning, a gain in weight of 0.45 kg/day or slightly over, and after weaning to mating at 15 months a gain of 0.64 kg/day, are satisfactory for future productive purposes (Lamond and Campbell, 1968; Warner, 1970b).

TABLE I: LIVEWEIGHTS AT VARIOUS STAGES OF DEVELOPMENT OF JERSEY AND FRIESIAN CATTLE (KG)

Breed	Weight at first service	Weight before first calving	Weight after first calving	Mature weight
Friesian	330	509	455	568
Jersey	218	327	291	364

(after Broster and Leaver, 1969)

It has been stressed that the most economic overall level of rearing will depend very much on the individual farm situation (Broster and Leaver, 1969). In New Zealand, mating heifers at 15 months of age to calve at 24 months suits the seasonal nature of dairy farming (Davey, 1976).

The question of the relationship between level of rearing, growth rate and adult performance has been reviewed by Allden (1970). The major productive issues are age at puberty, fertility when mating begins (and at subsequent breeding periods), dystocia, milk yield and life time in the herd.

i. Body Weight and Puberty

Growth can be accelerated or delayed with little influence on the final mature body size (Allden, 1970). However, puberty, which is the time at which reproduction first becomes possible (Asdell, 1968; Roberts, 1971) is a function of liveweight and is relatively independent of age (Sorensen *et al.*, 1959; Joubert, 1954, 1963). Thus onset of puberty as indicated by the occurrence of first oestrus is directly and positively related to growth rate and level of nutrition (Joubert, 1963).

Using varied planes of nutrition, Sorensen *et al.*, (1959) noted that Holstein heifers reached puberty at widely different ages but at relatively constant weights. The faster growing animals showed first oestrus at higher body weights than those growing at slower rates which is in contradiction to the results reported by Amir *et al.*, (1967) and Dufour (1975).

In Holsteins, at fast growth rates of 0.9 kg/day puberty appears at about 9 months of age, for average growth rates of 0.6 kg/day at 12-13 months, and for slow growth rates of 0.4 kg/day puberty may not be observed until 17-20 months of age (Crichton *et al.*, 1959; Swanson, 1967). Ovarian cycles may occur before oestrus is observed in slow growing heifers (Sorensen *et al.*, 1959). Weight at first oestrus in Holsteins has been reported to average from 250-274 kg (Salisbury and Van Demark, 1961) while age varies from 4 to 18 months (Fraser, 1971). According to the data of Joubert (1963), the weights at puberty of Jersey and Friesian heifers are in the range of 121-229 kg and 207-343 kg respectively.

A fast-slow growth feeding regime seems to have an adverse effect in that it delays sexual maturity (Crichton *et al.*, 1959) and reduces mature production (Schultz, 1969). Dufour (1975) recently observed that not only the duration but the time at which a fast growing regime is applied is important in attainment of puberty. Feeding regimes of high and moderate planes were imposed on Holstein heifers weaned at 5 months during two stages of growth:

a) an initial phase lasting 100 days and

b) a final phase immediately following the first and ending with ovariectomy at the second oestrus after puberty.

It was found that the high energy regime imposed after an initial phase of moderate growth was as effective in bringing about puberty as maintaining the high energy regime from weaning to puberty.

ii. Conception Rate and Dystocia

There is no evidence that growth restrictions in early life will influence the reproductive performance of cattle once a normal diet has been restored (Allden, 1970). Nevertheless, a slow growth rate, because of a low level feeding regime, will delay the breeding date of an animal and subsequently delay the time at which it comes into production. Besides delayed breeding, retarded growth may lead to dystocia in heifers (Broster and Leaver, 1969). Conversely, liberal feeding, although it leads to early breeding, may also give rise to dystocia especially at the first calving (Wickershaw and Schultz, 1963; Schultz, 1969; Gardner and Schuh, 1970; Gravert *et al.*, 1975). In fact, the increase in calving troubles is the most consistent problem with early breeding even though heifers appear to be well-grown. Reid *et al.*, 1964 (cited by Allden, 1970), feeding a high, medium and low plane of nutrition to three groups of heifers from birth to first calving, observed that at first calving the low group produced calves of lower birth weight and tended to have a higher number of cases of dystocia than the other groups. In their subsequent performance, there were no significant differences between groups in respect to either calf weights or calf mortality. Additionally, a high conception rate at first service was observed in heifers reared on the low level of nutrition. However, the authors argued that high plane heifers could have possibly been bred earlier at weights similar to those of heifers on the low plane; it is possible under these circumstances conception rates may have been different. Experimental results obtained at Cornell University and quoted by Schultz (1969) agreed with the above findings except for conception rates which were found to be similar in all groups.

Leaver and Yarrow (1975) indicated that the relationship between different levels of nutrition and conception rate was curvilinear with maximum conception rates (70%) at moderate intakes (growth rates of 0.4-0.6 kg/day). At lower and higher levels of intakes conception rates declined.

iii. Milk Yield and Composition

A low plane of nutrition during the rearing period is commonly but not invariable associated with a reduced milk yield in the first lactation. However, in subsequent lactation periods, low plane reared animals were superior in yield to cows which received a high plane of nutrition in early life (Allden, 1970). This apparent anomaly may be attributed to faulty udder development as a result of high level feeding since Swanson (1967) found that the udders of overfat heifers at the end of their second lactation possessed large depositions of adipose tissue and undeveloped alveolar spaces.

As far as milk composition is concerned, there is evidence indicating that it is not affected by level of rearing except for a slight increase in fat content during the early part of lactation with heifers reared on higher planes of nutrition (Crichton *et al.*, 1960; Davey, 1976). It is likely that such animals have utilised body depot fat for milk synthesis since they lost weight during the early lactation period.

Broster and Leaver (1969) point out that maximum milk yields had been obtained following rearing at 80-110% normal feeding standards.

iv. Longevity

Slowly reared animals have an appreciably longer production life than rapidly reared animals (Broster and Leaver, 1969; Allden, 1970). In terms of economics, the average length of productive life of dairy animals is important and an increase in longevity could lead to a greater supply of milk, and cheaper production (King, 1970). The decrease in length of productive life with increased levels of feeding during rearing may be associated with earlier age at maturity and subsequent earlier starting of the ageing process. Alternatively it may be due to the long term effects of increased physiological stress as indicated by their higher heart and respiration rates (Burt, 1956; Allden, 1970). King (1970) also noted that the average length of productive life tended to be shorter in herds with a high level of production. A further observation is that there was less sterility in the cows reared on a low plane of nutrition (Allden, 1970; Little, 1973).

However, it must be borne in mind that the advantages in longevity of slow rearing may be more apparent than real since there are many environmental hazards that can result in cows being culled from the herd (disease, accident, low production, poor fertility).

In summary the evidence suggests that both very low and very high levels of feeding from weaning to mating can have adverse effects upon productive and reproductive efficiency. However, underfeeding is undoubtedly more of a practical problem than overfeeding, and this is especially true in a grazing situation like New Zealand's where concentrate supplementation is rarely practised. An assessment by Davey (1976) of the relative importance of various factors related to the raising of dairy cattle over the growing period is given in Table II.

TABLE II. GENERAL EFFECTS OF UNDERFEEDING ON PRODUCTIVITY OF YOUNG DAIRY CATTLE

Effects	Assessment of importance	Remarks
Onset of puberty and time of calving	++++	
Calving difficulties	+	
Weight of calf	+	at extremes
Longevity	?	little evidence
Milk production		
first lactation	++	
second lactation	0	unless underfeeding extreme
Underfeeding immediately prior to calving	++++	
Underfeeding after calving	++++	

(after Davey, 1976)

SUBMISSION RATE

i. The Significance of Submission Rate

The objective of mating management in New Zealand dairy farming is to attain a concentrated calving i.e. 90% or more of the herd to calve in 6 weeks and with no more than 5% empty cows (Macmillan, 1972b). Such a calving pattern facilitates herd management as cows are at a similar stage of lactation and have similar feed requirements at any one time. Moreover, time saved through a shortened calving period means farmers can spend more time in caring for their calves.

In order to achieve a concentrated seasonal calving pattern, a large proportion of cows in the herd have to be submitted for breeding during a 4-week breeding period(Fielden and Macmillan, 1973; Macmillan *et al.*, 1975). Submission rate (SR) can therefore be defined as the percentage of the herd correctly identified in oestrus and bred during the first four weeks of the mating season. The second important factor which contributes to a concentrated calving is conception rate (CR) and it is defined as the percentage of cows which conceive to each insemination or mating within the breeding period (Macmillan, 1972a ; 1972b).

The interaction and importance of these two factors on subsequent calving performance has been stressed by Macmillan (1972b) and is illustrated in Table III

TABLE III: THE IMPORTANCE OF CR AND SR ON SUBSEQUENT CALVING PERFORMANCE

	CR	SR	4-week calving
Farm A	75%	70%	52%
Farm B	55%	90%	52%
Farm C	75%	95%	71%

(after Macmillan 1972b).

It is noted that both CR and SR have a complementary effect on subsequent calving rate. Conception rates in excess of seventy percent however are difficult to achieve and thus SR becomes of very great importance if the herd is to get in calf over a relatively short period of time.

Fielden and Macmillan (1973), from an investigation of 14 dairy herds, reported that 21% of the two year-old cows were not submitted during the first 28 days of mating even though most of these cows had post-partum intervals of more than 60 days. This was a much higher proportion of animals within the herds than occurred with the other age groups. A survey by Macmillan *et al.*, (1975) in the Taranaki district of New Zealand confirmed this finding in that submission rate problems occurred in herds of all sizes but that in most cases there was an age effect with two year-old heifers showing lower submission rates than older age groups.

While the initial ovarian activity that occurs post-partum is commonly associated with a high incidence of silent heat (Morrow, *et al.*, 1966), the lower submission rates in young cows referred to above is mainly associated with a lack of ovarian activity (Fielden *et al.*,1973). It is the mature cows which appear to experience genuine silent heats under New Zealand husbandry conditions (Macmillan, 1972b).

Moller (1970) has suggested that incomplete uterine involution may be the main reason for poor conception rates before 30 days post-partum while anovulation, silent heat and false heat are the main contributors to poor conception rates from 30-40 days post-partum.

ii. Body Weight and Submission Rate

Moller (cited by Fielden *et al.*,1976) has pointed out that there is a positive relationship between body weight and submission rate (see Table IV). The body weights for yearlings in this study were measured just prior to the beginning of the mating period while those of the cows were taken just before calving for the herd began.

Though there is limited information covering this association there appears to be widespread acceptance that this relationship between body weight and submission rate exists.

TABLE IV: RELATIONSHIP BETWEEN BODY WEIGHT AND 28-DAY SUBMISSION RATE (SR).

Jersey yearling (heifers)			Friesian x Jersey yearlings (heifers)		
n	Weight (kg)	28 day SR	n	Weight (kg)	28 day SR
42	<180	76%	16	<200	81%
34	180-190	82%	20	200-210	95%
44	190-200	93%	26	211-220	96%
Jersey 2 years (heifers			Friesian x Jersey 2 years (Heifers)		
87	<275	72%	28	<300	57%
96	275-300	85%	62	300-350	74%
212	>300	93%	26	>350	81%
Mature Jersey cows			Mature Friesian x Jersey cows		
179	<325	78%	27	<350	70%
229	325-375	87%	89	350-400	84%
313	>375	88%	77	>400	90%

(after Fielden *et al.*,1976)

iii. Factors affecting Submission Rate

a. Efficiency of oestrus detection

This is a major factor influencing submission rate. Without accurate oestrus detection, it is not possible to assess accurately the effect of other factors (Macmillan, 1972a, 1972b). Inefficient detection of oestrus will lead to a false estimate of the submission rate either because cows which are in oestrus are not recognised or because cows which are not in oestrus are wrongly diagnosed as being in oestrus.

The economic importance of oestrus detection has been well documented by Esslemont (1974a). In New Zealand evidence suggests that the standard of detection is high enough to ensure a calving interval of 365 days; this level of performance is usually achieved however by using liberal oestrus detection methods and high culling rates (Macmillan, 1976). The incidence of short return intervals (1-17 days) which increased from 11% in 1964 to 20-25% in 1970 reflects this tendency to interpret oestrus liberally, even though genuine short return intervals of less than 17 days (9-11 days) do exist (Macmillan, 1976). In Ireland, Hartigan (1972) also observed that the highest incidence of short cycles occurred on days 9 to 11 of the cycle and that the incidence of such cycles increased with increasing herd size.

The detection of oestrus in dairy cattle presents several problems to the farmer (Pope *et al.*,1976). This can be anticipated since there is great variation in the intensity of the behavioural changes associated with the phenomenon (Esslemont and Bryant, 1974). The problem is compounded by difficulties in allocating enough time for oestrus detection especially in larger herds (Esslemont, 1974b). The important types of errors in oestrus detection and their identification to improve efficiency of detection have been discussed by Macmillan (1976).

It is worth noting that the study of Williamson *et al.*,(1972) demonstrated that visual observation alone, except when it is carried out continuously 24 hours a day, does not give a high detection efficiency. Since continuous observation by farm workers is not a practical solution under New Zealand conditions of farming, other detecting devices must be used in conjunction with visual observations in order to obtain high detection rates. Such devices include the use of vasectomised marker bulls, heat mount detectors and tail painting all of which have been reported to produce good results (Shrestha, 1978). Tail painting as a method of detection is a particularly convenient and low cost technique (Macmillan and Curnow, 1977).

b. Anoestrous Syndrome

Anoestrus may be defined as failure to show overt signs of oestrus (Fielden *et al.*,1976). Defined in this way it is not necessarily synonymous with ovarian inactivity since there may be many factors which can lead to the visible signs of heat in cattle being suppressed. 'Anoestrous syndrome' may thus be a better term for this phenomenon. Conveniently, the 'anoestrous syndrome' can be classified as of the pre-service or post-service type. Obviously, submission rate will be affected by pre-service anoestrus.

An investigation of 294 herds in the Taranaki district indicated that the 'pre-service anoestrous syndrome' was the major cause for cows not being submitted for mating during the 4 weeks of the breeding period; this problem was intensified in young animals (Fielden and Macmillan, 1973). Additional findings from a further investigation of cows in herds in the Manawatu/Wairarapa districts is shown in Table V.

TABLE V: OVARIAN STATUS OF COWS SHOWING 'PRE-SERVICE ANOESTROUS SYNDROME'

Age at calving	No. of examinations	% inactive ovaries
2 year	1028	85
3 year	438	74
4 and over	808	47

(after Fielden *et al.*, 1976)

The high incidence of inactive ovaries in 2 year olds was attributed to the combined effects of meeting their nutritional demands for growth and lactation as well as coping with social stresses within the herd (Fielden *et al.*, 1976). This problem of 'pre-service anoestrous syndrome' although of temporary nature is expensive in terms of time lost before breeding can commence after calving.

Anoestrus in dairy cattle has been reviewed by Morrow (1969a) and further considerations of the problem as it exists in New Zealand can be found in the reports of Fielden *et al.*, (1976).

c. Post-calving interval

After parturition, animals need some time for proper uterine involution and the re-establishment of ovarian activity to occur. American workers (Marion and Gier, 1968; Wagner and Oxenreider, 1971) have indicated that the process of uterine involution is complete within 21-30 days of parturition and that the first ovulation occurs within 40 days. Mature cows ovulate earlier in the post-partum period than the young cows. Moller (1970) reported that mature cows experienced their first post-partum ovulation at an average of 36 days compared with 52 days for 2 year and 3 year-old cows.

Apart from the post-partum period required before cyclical activity recommences in the cow after she has calved, the post-partum period that elapses before first mating after calving markedly influences fertility. Thus, when the interval from calving to mating is less than 60 days, chances of conception are reduced (Olds and Cooper, 1970; Macmillan, 1972a; Whitmore *et al.*, 1974; Britt, 1975). The influence of this interval on conception rates is shown in Table VI.

TABLE VI: THE INFLUENCE OF INTERVAL FROM CALVING TO MATING ON CONCEPTION RATES

	Post-partum interval		
	Under 40 days	40-59 days	At least 60 days
2 year-old cows	52%	59%	65%
Older cows	40%	58%	68%

(after Macmillan, 1972a).

Britt (1975) in a review, estimated that fertility was 25% for cows bred during the first 20 days after calving, then increased to about 60% at 60 days post-partum and stabilised thereafter. Apparently, mating cows within 60 days post-partum gives lower conception rates and requires more services/conception, but it has no cumulative detrimental effect on fertility (Britt, 1975).

d. Multiple suckling

Macmillan (1972b) indicated that multiple suckling increased both the duration of anoestrus and the incidence of silent heat.

Saiduddin *et al.*, (1967) working with primiparous Holstein cows, noted that the mean interval from parturition to first oestrus was 30 days and 45 days for non-suckled and suckled cows respectively. Similarly, Baker (1967) found a high correlation between the length of the suckling period and the interval to first oestrus. In his subsequent studies however, when the body weight of the animals was significantly higher, this correlation was no longer significant. Thus the question of whether the nutritional status of the animal can compensate for the the effect of suckling is unresolved.

Using the criterion of ovarian growth, Moller (1970) noted highly significant differences in ovarian size between cows milked and cows suckled twice per day or continuously. This same author also noted a 57% silent heat occurrence in milked cows when ovulation occurred during the first 60 days after calving as compared to a 100% occurrence in the same period for suckled cows.

The evidence then clearly demonstrates that the suckling stimulus delays the onset of ovarian activity and the degree of this delay is influenced by the suckling intensity.

e. Management factors

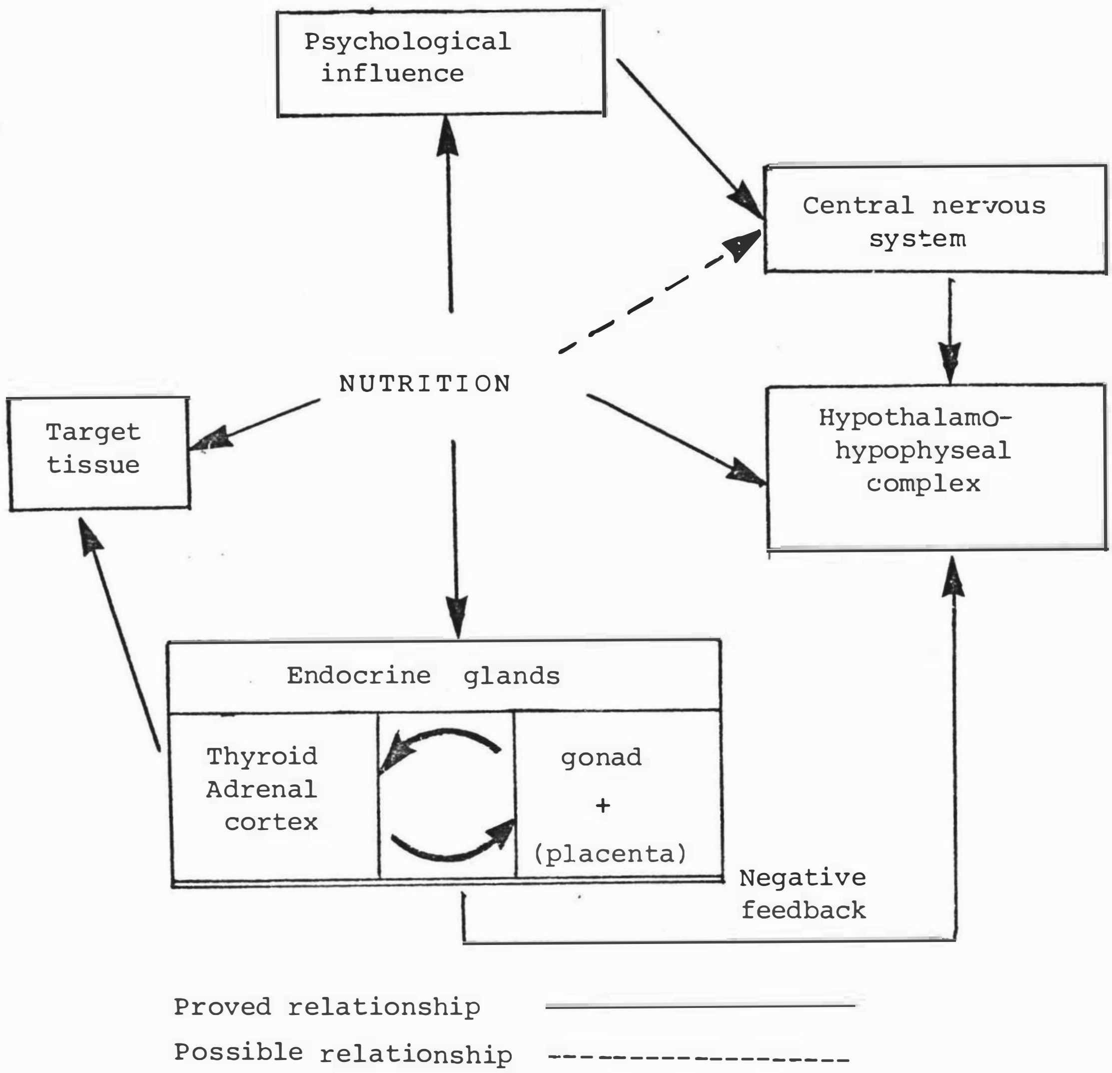
Managerial decisions can influence submission rates, for example decisions as to whether a particular individual in the herd should be bred or not. Furthermore, with the current emphasis that has been placed on concentrated calving patterns in New Zealand, together with the realisation that an initial breeding of a cow not in heat has little if any detrimental effect (Macmillan *et al.*, 1977a), liberal interpretation of oestrus tends to result in an artificially high submission rate.

BODY WEIGHT AND FERTILITY

i. Physiological Basis of Nutritional Infertility

There is no simple relationship between nutrition and reproduction (Lamming, 1973). The direct and some indirect effects of nutrition on reproduction can be diagramatically represented as in Figure 1. Not all the implications shown in this figure have been proven beyond doubt and this is particularly true of those

Figure 1: The Effects of Nutrition on Reproduction



(after Lamming, 1973)

aspects involving the influence of nutrition on gonadotropin secretion and release (Lamming, 1973).

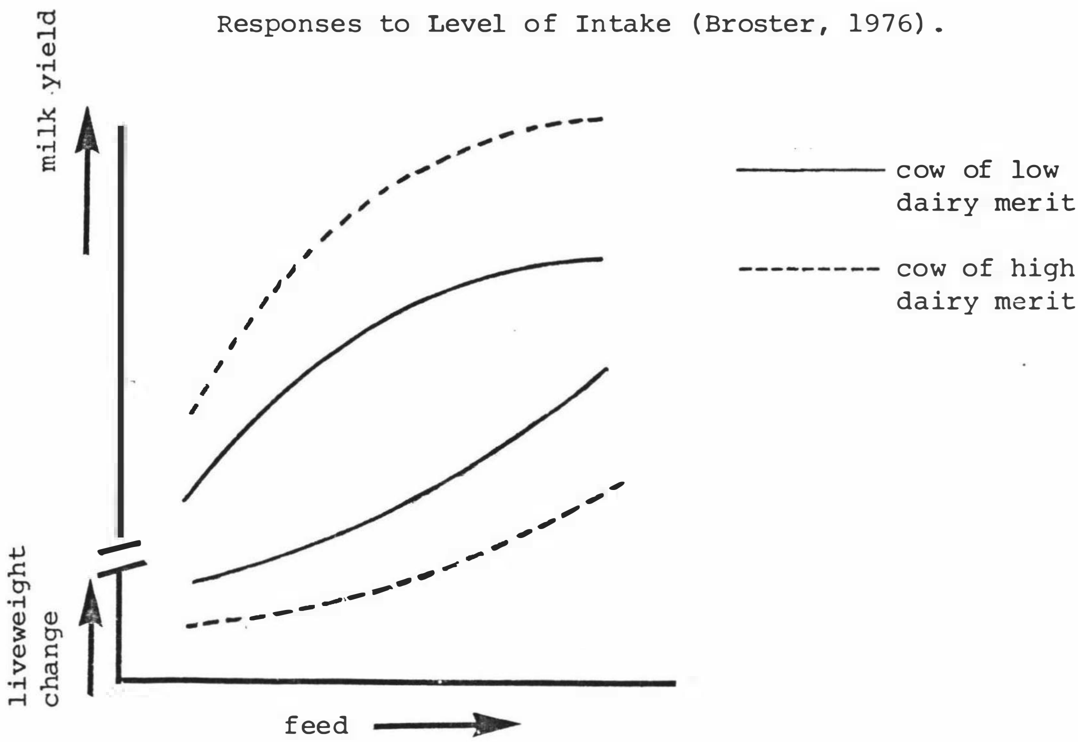
Manipulation of nutrient intake has characteristic effects on the ovary. Thus Wiltbank *et al.*, (1964) and Lamond (1968) have related reduced follicular development to poor nutrient intake in the cow. A short-term low plane of nutrition has been also shown to reduce follicle numbers and plasma progesterone levels in beef heifers (Hill *et al.*, 1970). It is not clear if this is a primary effect of undernutrition; generally nutritional influences on the activity of the gonads are believed to be mediated directly or indirectly via the pituitary gland rather than directly on the gonads (Lamming, 1973).

ii. Partition of Nutrients

It is said that the cow divides its food, maintenance needs apart, between milk production and liveweight (Broster, 1972). Further division of nutrients between milk production and liveweight is related to the cow's milk yield potential, her stage of lactation and her level of food intake (Moe *et al.*, 1971; Broster, 1972). However, under conditions of nutritional inadequacy, milk production is attained at the expense of body reserves as seen in early lactation (Broster, 1972; Bines, 1976). Inadequacy in nutrition may be due to a frank short supply of feed to the animal but it is generally a consequence of the genetic ability of the animal to produce milk during early lactation which exceeds its ability to ingest sufficient feed to meet its requirements for energy. Since production of milk during early lactation has a high priority in the dairy cow, production of milk may continue at high levels despite an insufficient dietary energy intake (Moe *et al.*, 1971). This is possible because the cow has the ability to draw upon its tissue reserves to provide the energy which is lacking in the diet. The amount of tissue energy used for this purpose will depend on the condition of the cow at the time of parturition, the genetic potential of the animal for milk production, the feed intake during early lactation (Moe *et al.*, 1971) and the magnitude of the negative energy balance which can exist without the production of ketosis (Chalupa, 1974).

Understandably, liveweight losses are associated with high levels of milk production and/or low levels of intake. The manner in which the cow's yield and rate of liveweight change respond independently or jointly to the plane of nutrition is illustrated in Figure 2. Cows of greater dairy merit produce more milk and show less liveweight gain from a given amount of food. Conversely, the low yielders increase in body weight at the expense of milk yield.

Figure 2: Simplified Model to Describe the Relationship of Food to Milk and Liveweight in Dairy Cows according to Responses to Level of Intake (Broster, 1976).



iii Pattern of Liveweight Change

Changes in liveweight of lactating cows result from a combination of growth, pregnancy and alternate deposition and subsequent catabolism of body fat tissue (Miller *et al.*, 1969). Usually, losses of liveweight are observed in early lactation where milk yields are high and voluntary intake is inadequate. Hutton (1963) observed that the intake of pasture did not reach its maximum until five months after calving and that cows in early lactation were in a state of negative energy balance and lost weight. His reports applied to grass fed cattle. Exceptions to this general rule have been noted in heifers severely underfed before calving, in beef heifers of low milk yield potential, and in cows fed dried herbage and barley diets (Broster, 1976). The reasons for this inability of cows to consume enough food to meet their demand, particularly in early lactation, is not yet clear. Food intake actually increases within a few days after parturition but at a rate which is slower in terms of energy input than the increasing rate of energy output in milk (Forbes, 1970; Bines, 1976). Removal of the foetus and associated tissues at parturition will increase considerably abdominal capacity and this in turn would be expected to permit a greater rumen fill. Perhaps, as suggested by Bines (1976), fat deposited within the abdomen before calving has to be mobilized before rumen fill can be maximised.

Studies have shown that the increasing volume of the uterus and fat deposited within the abdomen both cause a reduction in rumen capacity in the last stages of pregnancy and lead to a decline in roughage intake during this period (Forbes, 1970; Bines, 1976; Journet and Remond, 1976). With diets where intake is not thought to be limited physically, some metabolic factors might cause the decline in intake; a high level of oestrogen is suspected to be such a factor (Bines, 1976). Another possibility is that the rate of metabolism in both the rumen and other tissues takes time to adapt after calving to the increased demand for nutrients (Bines, 1976). The long time needed for the breakdown of food into fine particles by chewing and by rumen microbial digestion may also be a limiting factor since in feeding trials a rapid and significant increase in the intake of pelleted ground feeds, compared to long forages, has been noted after calving (Journet and Remond, 1976).

As the cow moves through lactation, milk yield and its responsiveness to variation in intake decreases (Burt, 1956; Broster *et al.*, 1969). A greater responsiveness in liveweight change would therefore be expected but evidence that this is in fact so is limited (Broster *et al.*, 1975). Nevertheless, the weight of the cow generally stabilises around the sixth week after parturition and thereafter may be expected to start to rise as mid-lactation proceeds (Miller *et al.* 1969), Broster, 1973).

The extent of the fall in weight in early lactation and the subsequent weight gain depend both on the level of feeding offered the animal as well as the type of ration. When a ration high in concentrates was given *ad libitum* to cows after parturition, a significant increase in energy intake resulted thus reducing the interval between peak yield and peak intake; a complete balance between intake and output of energy did not occur however and liveweight losses still occurred in all animals (Broster and Strickland, 1977).

The effect of feeding varying levels of supplementary concentrates to grazing dairy cows has been comprehensively reviewed by Leaver *et al.*, (1968). They concluded that there was not a marked advantage from feeding concentrates to moderate yielding cows at grass. Similarly, Taparia and Davey (1969) found that feeding concentrates depressed voluntary intake of pasture and had little effect on milk yield. This supplementation with concentrates resulted in a decrease of about 0.65 kg pasture dry matter intake per kg concentrate dry matter consumed. In addition, there were no significant differences in liveweight gain between concentrate supplemented groups at either 2.7 kg or 4 kg per day of concentrate per head and the pasture fed *ad libitum* group. Clearly, concentrate feeding is wasteful when such feed-stuffs become a substitute for pasture. However, concentrates can play a useful role in offsetting short-term feed shortages which are prone to occur under some situations of high stocking rate (Leaver *et al.*, 1968).

iv. The Relationship Between Body Condition and Fertility

Size of animal varies between and within breeds. Linear measurements such as height to wither may be a better measure of size but body weight is commonly used. For grazing lactating cows, body weight measurements can provide a reasonable but crude estimate of their nutritional states. These body weight measurements can be misleading in herds subject to marked changes in food types (McClure, 1970). A heavy animal does not necessarily mean that it is in good condition.

The term body condition, on the other hand, is the degree of fatness shown by the animal. It is independent of the size of the animal or gut fill and it reflects the animals recent nutritional history. Investigations at the National Institute for Research in Dairying (Pope *et al.*, 1976) with cattle classified as having poor, moderate and good or very good body condition had shown that the pregnancy rates (50-70 days after A.I.) of maiden heifers were 42, 72, 60 and 63% and of lactating cows, 43, 57, 63 and 46% respectively in each category of body condition.

Body condition scoring is usually based on some numerical scale. At Ruakura, a scale of 1 - 10 is used and cows at grade 5 are considered to be in ideal condition for calving (Trigg and Cook, 1977). Also, a condition grade change of 1 is taken to be equivalent to about 30 kg liveweight in mature cows and 35 kg in heifers. Understandably, visual assessment of body condition is more reliable in experienced eyes.

v. The Relationship Between Body Weight Change and Fertility

McClure (1965) from a study of Jersey herds in New Zealand, had observed that the infertile cows were those which lost the most weight between calving and mating and/or were still losing weight at the time of mating. In another study, the same author (McClure, 1970) found that although weight change was related to fertility, the relationship was not a strong one. Two groups of cows which lost weight in the last two weeks before mating at a rate of 7.8 kg and 9.9 kg per cow per week still had normal non-return rates of 69% and 67% respectively.

King (1968) in a study of 179 Ayrshire cows, similarly noted that 98 cows which gained in body weight during the breeding period had a higher conception rate to first service (77.6%) than did the 81 cows which lost weight (16%). Additionally, in the latter group, none of the 8 cows which lost over 25.5 kg bodyweight held to service (see Table VII).

TABLE VII: EFFECT OF CHANGE IN BODY WEIGHT ON FERTILITY OF DAIRY COWS (King, 1968)

Total no. of cows	No. of cows conceived	Change in body weight over 4 week period (kg)	Conception rate (%)
		Rises	
2	2	47.7 and over	100
4	4	38.2 - 47.3	100
10	10	25.5 - 37.7	100
31	24	12.7 - 25.0	77.4
51	36	0.45 - 12.3	70.6
		Sub-total	77.6
		Falls	
41	11	0.45 - 12.3	26.8
32	2	12.7 - 25.0	6.2
8	0	25.5 - 37.7	0
		Sub-total	16.0

In a further study (Pope *et al.*, 1976), lasting from six weeks before to six weeks after mating, heifers which were fed to gain weight daily had a pregnancy rate of 68% as compared to 45% in a second group which were losing 0.25 kg/day.

Further evidence for this positive association between animals gaining weight and higher pregnancy rates comes from work with beef cattle reported by Wiltbank *et al.*,(1962; 1964), Dunn *et al.*, (1964) and Donaldson *et al.*,(1967).

In contrast to the above findings, Boyd (1972) reported that while there was a benefit to conception when the cow was gaining weight, this was not statistically significant and a loss of liveweight was not detrimental to fertility. Similarly Broster (1973), in a review of the topic, suggested that there was no conclusive relationship between fertility and liveweight change for cattle receiving moderate to generous planes of nutrition. Furthermore, based on his own work, he found that a moderately inadequate ration in the first sixteen weeks of lactation did not affect the fertility of Friesian heifers calving for the first time at about two-and-three-quarter years of age.

The ability to conceive may be more a function of body weight *per se* and not a state of changing body weight during the post-partum period (Richardson *et al.*, 1975). Supporting evidence for this was noted in the work of Steenkamp *et al.*, (1975) while Lamond (1970), also expressed the opinion that fat heifers may show good rates of fertility though currently losing weight. Moller and Shannon (1972) on the other hand noted for cows mated 30 - 59 days and more than 59 days post-partum that those gaining weight had significantly higher non-return rates than those maintaining body weight.

While more information is yet required to clarify this relationship between body weight change and fertility, it is clear that animals at the lower end of the weight and body condition distribution within an age group at the time of breeding have poorer breeding performance. There may well be, however, some type of threshold above which such a relationship does not apply.

vi. Factors which may Influence the Relationship between Liveweight and Fertility.

a. Protein - energy relationships.

It is probably true that the plane of nutrition affects reproduction by virtue of its carbohydrate and energy content. However, nutritional infertility may be caused by other nutrient deficiencies. Much of the evidence relating reduced fertility to plane of nutrition, as outlined by Broster (1973), McClure (1975) and Topps (1977), does not allow this distinction to be made. Roberts (1971) based on clinical observations, has indicated that most field cases of reduced fertility or sterility of nutritional origin are usually due to multiple deficiencies.

There is an optimal balance between protein and energy. Gould (1969) has suggested that an excess of protein can lower the fertility status. The primary effect of this excess of crude protein is to make food unpalatable; this results in a reduction of feed intake and thus of energy levels.

b. Yield level and fertility

Opinions regarding the relationship between production and fertility remain varied and conclusions confused.

According to a recent literature review by Shrestha (1978), many of the reports which indicate an inverse relationship between production and fertility have been based on total milk production rather than the level of production prior to and during the actual breeding period. The problem is that total milk production can be significantly influenced by lactation length and by the presence or otherwise of a conceptus. It is thus difficult to say if high production is either the cause or effect of poor conception rates.

Other reports relating 'conception rate' to level of production prior to or during the breeding period have indicated that where negative correlations exist they are small and of little consequence (Shrestha, 1978).

c. Pre- and post-calving feeding

Plane of nutrition, both before and after parturition, influences reproductive performance. Wiltbank *et al.*, (1964) observed in beef cattle that there was a cumulative effect on fertility of the level of feeding during pregnancy with the level of feeding during lactation. Either, if inadequate, can reduce fertility but the effect of low post-calving feeding increased when it followed a low level of feeding before calving. Hight (1968) also noted that high planes of nutrition after calving partially overcome the infertility effect caused by a low plane during late pregnancy. Turman *et al.*, (1964) found that a low nutritive level for heifers during their first pregnancy had a detrimental carry over effect on reproductive performance at their second mating season.

Furthermore, the time that the nutritional inadequacy occurs influences the outcome; thus low intakes of food energy during the pre-calving period result in an increased time to the first post-partum oestrus while low intakes of food energy post-calving have a more significant effect on the conception rate to first service (Wiltbank *et al.*, 1962; 1964).

d. Level of Feeding Immediately Around the Time of Service

A relationship between the reproductive performance of sheep and the level of feeding immediately prior to mating is well established (Coop, 1966). Whether a similar relationship holds for cattle is not clear.

Lamond (1970) considers that very generous feeding before service might be of limited value to animals in poor condition but possibly wasteful for animals already in good condition. Fielden (1976) also stresses that short term alterations of feed input appear to have remarkably little effect on return to cyclical activity if the animal concerned is in a 'reproductively unfit' condition. Similarly, Youdan and King (1977) indicate that it is unlikely that an increase in nutrient intake at or about the time of service, with the object of rapidly increasing body weight, would improve fertility.

Brochard (cited by Broster, 1973) pointed out that the plane of nutrition immediately after service might be critical to the survival of the fertilised egg. McClure (1972), citing evidence from studies with mice, stated that starvation immediately before or after mating reduced fertility; the primary biochemical change associated with this infertility appeared to be a fall in blood glucose. This same author thus commented that cows may behave like the laboratory rodents since hypoglycemia had been noted in infertile cows.

TARGET BODY WEIGHTS

The idea that maiden heifers should be well grown for age at the time of breeding and that cows should be in good condition at calving is in line with the concept of Lamond (1968; 1970) of a target weight. According to this author, each cow, depending on heredity, age, lactational status and time of year has a high probability of conception within a certain range of body weights and body condition. If this concept holds true, then a main concern in management will be to achieve the target weight for a particular class of cow using a feeding regime that will be economically sound.

i. Target Body Weights for Maiden Heifers.

As discussed previously, heifers must attain a certain weight before they will show oestrus; calving problems also are related to the size and physical condition of the heifers. Thus, according to Brody (quoted by Joubert, 1954), body weight rather than age should be used as the criterion for first breeding of farm animals; dairy heifers should be first bred when they reach two-thirds of their expected mature body weight.

Hight (1966) has recommended that British breed beef heifers should weigh 273 to 295 kg to allow mating at fifteen months. Young (1967) on the other hand, found that liveweight at first mating had little influence on the ability of heifers to become pregnant. Olds *et al.*, (1952) had also noted earlier that size ranges from 182 to 455 kg* in weight caused little or no effect on the fertility of Friesian heifers.

More recently, Hanly and Mossman (1977) have put forward the concept of 'critical minimum weights' for mating yearling beef heifers. They define the 'critical minimum weights' as the average weight of the breed or crossbred required to attain an 84 to 95% pregnancy rate over a 42 to 45 day mating period. Any heifer has the potential to become pregnant once it has reached puberty but what is more important is the re-breeding performance during the next season according to these authors. Mating yearling heifers below a certain minimum weight will invite reproductive problems and increase the culling rate of second or third calvers.

Better performances at higher body weights have been reported by Ellis (1974) who found that the percentage of heifers calving increased linearly with increasing joining weight from 175 to 265 kg at the rate of 7% for each 10 kg increase in weight; increased calving rates with higher mating weights were also observed by Buck *et al.*, (1976). Further support for this concept is noted from the work of Harwin *et al.*, (1967), Pope (1967) and Sparke and Lamond (1968) and the results of two of these groups of authors are shown in Table VIII.

* Weight estimated from chest girth by Salisbury and Van Demark (1961).

TABLE VIII: EFFECTS OF WEIGHT AT BREEDING AGE ON REPRODUCTIVE PERFORMANCE OF HEIFERS

Age and breed	Weight (kg)	Calving rate (% of total)	Reference
2 year old Afrikander	>318	100	Harwin *et al*., (1967)
	250 - 317	83	
	<250	60	
2 year old Shorthorn-Devon crosses	252	74	Sparke and Lamond (1968)
	226	55	
	191	4	
	<178	0	
3 year old Shorthorn-Devon crosses	285	100	Sparke and Lamond (1968)
	236 - 254	77	
	216	33	

For dairy heifers, Moller (quoted by Fielden, 1976) has suggested a minimum body weight of 190 kg for Jersey yearlings and 200 kg for Friesian-Jersey cross yearlings in obtaining optimal submission rates when breeding these animals at the age of fifteen months.

Davey (1976), after having examined the results of experimental and survey work both in New Zealand and overseas, has put forward his recommendation about the optimal weight for first breeding at fifteen months, and between mating and calving, for Jersey and Friesian heifers as illustrated in Figures 3 and 4.

To reach these targets, maiden Jersey heifers need to grow at least at a rate of 0.4 kg/day from birth to mating; crosses and Friesians at slightly greater rates (Davey, 1976; Fielden, 1976).

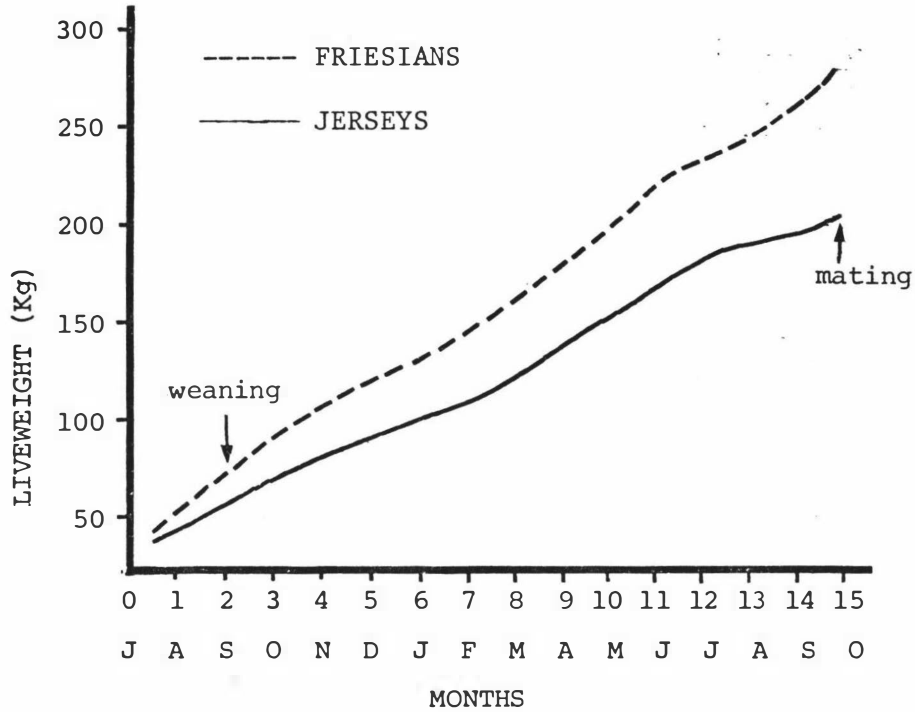


Fig. 3: Recommended target live weights for Jersey and Friesian cattle between birth and mating (Davey, 1976)

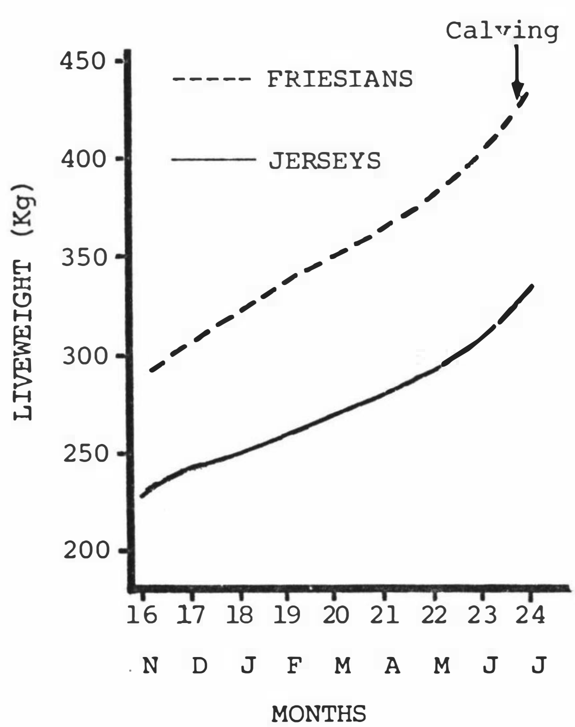


Fig. 4: Recommended target live weights for Jersey and Friesian cattle between mating and calving (Davey, 1976)

Even though it has been stressed that body weight is the main criterion for first breeding of cattle, there is an age below which they should not be bred since rearing experiments have shown that heifers bred at a very early age have given disappointing milk yields in spite of having achieved adequate body weights at the time of breeding (A.D.A.S., 1973). This advisory body in the United Kingdom suggests that no heifer should be first bred before fourteen months of age. Wickershaw and Schultz (1963) also found that first lactation milk and fat production increases as age at first breeding increases. In a previous review of early breeding Schultz (1969) concluded that breeding after eleven months was more desirable than breeding earlier; Warner (1970b) added a further recommendation that breeding should preferably be carried out after the heifers had experienced two or three oestrous cycles.

It is worthwhile noting that the nutrient requirements of young stock account for about 15% of the total food supply on the farm. Thus a moderate increase in the level of feeding in order to attain appropriate target weights at mating and at calving are unlikely to have profound effects on the overall feed supplies of the property (Davey, 1976).

Since in a grazing situation the growth rate of heifers is dependent upon the available pasture it may be justified to use supplements during the period where there is a shortage of grass. Following trials carried out at Massey University, Halford (1976) suggested that meal feeding could be the cheapest feasible way of achieving high growth rates. The use of meal feeding could then be extremely useful to yearling heifers when their previous growth rates have been curtailed if target weights are to be achieved.

ii. Target Pre-Calving Weights for Cows

Target live weights immediately prior to calving as suggested by Bryant (1977) are shown in Table IX. These can be achieved by periodic weighings of the animals and appropriate feeding.

TABLE IX: TARGET WEIGHTS IMMEDIATELY PRIOR TO CALVING (KG) (Bryant, 1977)

Age (year)	Jersey	Friesian
2	320	410
3	380	460
4+	420	540
Herd average	385	470

Moller (see Fielden *et al.*, 1976) has suggested target live weights of 350 kg and 400 kg just before calving for two year and mature Friesian-Jersey crosses respectively.

Among the various age groups, particular attention in management should be given to the two year old lactating cows. These young animals are still at a stage of continuous growth and lactation places a severe strain on them (Fielden *et al.*, 1976). Furthermore, they have to compete with older and more mature cows for the available feed under pasture grazing conditions. If they fail to compete, inadequacy of nutrition will affect their production, delay their sexual activity and increase final culling rates (McClure, 1975). Obviously such a problem is most likely to occur in large herds where competition between animals is high.

Topps (1977) has stressed that post-partum infertility is an anoestrus induced by the action of undernutrition and lactation with the two factors probably being inter-related. Additionally, younger animals undergoing their first lactation, being smaller than the mature cows, are likely to have smaller reserves thus making them even more vunerable to post-partum infertility. In such circumstances, management aimed at feeding young cows separately from old cows may result in the young cows getting a fairer share of the feed.

The realisation of target weights at calving is primarily dependent on liveweight at drying off, the length of the dry period (which depends on drying-off date under seasonal dairying conditions in New Zealand) and available feed supplies (Bryant, 1977; Trigg and Cook, 1977). The drying-off date can be easily manipulated and therefore provides a valuable management means of getting cows to a satisfactory condition at calving. Decision on the time for drying-off has to be based on cow condition at that time, feed supplies both presently available and anticipated, cow requirements up to calving and the time available in which cow target liveweights can be realistically achieved (Trigg and Cook, 1977). Under pasture grazing conditions flexibility in management is generally necessary to meet specific goals in any one season.

MATERIALS AND METHODS

i. Location and Animals

Parous cows.

Observations were recorded during 1976-1977 on 191 (169 F, 22 F x J)+, 112 (76 F, 36 F x J), 91 (53 F, 38 F x J) and 73 (18 F, 55 F x J) Friesian and Friesian Jersey crossbred parous cows in herds I, II, III and IV respectively. These seasonal supply dairy herds were located on the outskirts of the city of Palmerston North in the Manawatu. They were selected because of the willing co-operation shown by the owners and their reliability in record keeping known through previous work carried out on these properties. In addition these properties had animals of similar genetic background which were predominantly Friesians or crossbreds having 3/4 Friesian blood and whose ages were known.

The management of these cows on grazing pastures was as commonly practised by seasonal supply dairy farmers in New Zealand. Where feed shortages occurred in early lactation supplementary hay or silage was fed in addition to grass fed *in situ*.

Yearling heifers (non-parous)

The data on the yearling heifers were obtained from five herds, of which four were from the same locality as the cow herds. Herd I contributed observations on 47 yearlings and Herd III 17 yearlings while Herds V and VI provided 14 and 20 yearlings respectively. Herd VII, comprised of 86 yearlings, was located at Ruakura Animal Research Centre, Hamilton. The data for Herd VII was accumulated over a five year period. For all yearling herds, only animals of 3/4 Friesian blood or more were selected for use.

The yearling heifers were grazed and managed as a separate group from all other animals on their respective properties and were given access to abundant pasture at all times.

+ F = Friesian J = Jersey

ii. Records and Measurement

Parous cows

In the cow herds, animals were identified by either plastic and/or metal ear-tags. Ages were determined from breeding records kept by the farmers. The body weights of all cows, without prior fasting, were taken by means of a portable weighing scale ('Tiki scale')* just before the first animal was due to calve in the herd. All animals of the same age group on each property were weighed at the same time. In most of the cases, weighing took place at 10.30 am.

An animal was considered as being submitted for breeding when she was put forward for insemination within the first four weeks of the breeding period. All breedings were by licensed inseminators using semen provided by the Wellington Hawkes Eay Livestock Improvement Association.

Calving dates were used to determine the pregnancy rate in all herds. In this context, pregnancy rate was defined as the percentage of animals which became pregnant as a result of being mated within the first four weeks of the breeding period. The calving date was related to the service date based on a gestation period of 280 days with an allowance of ± 12 days. Where there was more than one service during the first four-week breeding period, the date which fitted closest to a 280-day gestation length was recorded as being the service to which conception occurred. In Herd I, pregnancy examinations were carried out by a veterinarian experienced in such work four months after the end of breeding period; the pregnancy examination results were used in association with the subsequent calving dates to calculate the pregnancy rate of the cows in that herd.

Yearling heifers

With the yearling heifers, a similar pattern of identification to that used for the cows was adopted in herds III and V while those animals in herds I and VI were identified by a number applied on their side with a bleach type product ('Ani-mark') obtained from the Awahuri Artificial Breeding Centre. The weights of the yearling heifers were measured immediately before the breeding period began. In Herd I, a hydraulic type scale ('Donald')**already on the property was used to measure the weights of animals while in the three

*
** see p.38

other herds the same portable scale as for obtaining the cow weights was used. Identification numbers were applied at the time of weighing; all weights were measured within 2-3 hours of the yearling heifers coming off pasture.

Yearling heifers were mated to young bulls equipped with a chin-ball mating harness ('Paviour')*** which was checked and refilled every week. For Herd I, two bulls were put out in the first week and after that only one bull was maintained with the group at any one time. In the other herds, one bull was used throughout the four-week breeding period. The yearling heifers were inspected at weekly intervals and those with paint marks on their rumps were recorded as having been in heat and bred. Pregnancy examinations were carried out in herds I, III and V at 8-9 weeks after the end of the mating period while Herd VI was examined 16 weeks after breeding ended. Both the results of the pregnancy examinations and calving dates were used to estimate the pregnancy rate except for Herd VI where only pregnancy examination data were available.

In Herd VII (Ruakura Animal Research Station's herd) data were obtained by the courtesy of the management of the No.2 Dairy Unit. Their method of determining mating dates and pregnancy rates was basically the same as that described for the other herds in the project.

iii. Method of Analysis

Analysis of variance was used to study the effect of herd and age and their interaction on body weight in the four seasonal supply cow herds studied. Analysis of variance for herd differences in body weight was also carried out for the five yearling herds.

Any between year differences for the yearling data for Herd VII were ignored. Although there were significant differences in body weights between years for the yearling heifers in this herd, there was no significant difference in either submission rate (S.R.) or pregnancy rate (P.R.) response whether the heifers in the different years were analysed by either Method A or B as outlined below. The data for Herd VII, although accumulated over a five-year

*** see p38

period, was therefore treated as if it were for one year only to facilitate analysis with the information from the other herds.

To describe the association between the body weights of the animals in the study and their relationship, if any, to S.R. and P.R., the data was handled in two ways.

Method A: Within an age group within a herd, animals were classified on the basis of body weight into six groups as follows:-

A = animals of lower body weight than 1 standard deviation (S.D.) below the mean for that age group in that herd.

B = animals of body weight between ½ S.D. and 1 S.D. below the mean for that age group in that herd.

C = animals of body weight between ½ S.D. below the mean and the mean for that age group in that herd.

D = animals of body weight between ½ S.D. above the mean and the mean for that age group in that herd.

E = animals of body weight between ½ S.D. and 1 S.D. above the mean for that age group in that herd.

F = animals of higher body weight than 1 S.D. above the mean for that age group in that herd.

Within these subclasses, the numberswhich were either submitted for service or became pregnant within the defined period were calculated. These were then summed for each subclass and the percentage value obtained for use in the subsequent analyses (see Table XIV).

The objective of this approach was to remove individual herd effects.

Method B: In this method, the individual herd effects were ignored. Animals of the same age group from all the herds were pooled to obtain a common mean body weight. The animals were then divided into six groups on the same basis as before and the submission rates and pregnancy rates calculated.

The regression lines for S.R. and P.R. on body weight were analysed by the least squares method using second degree orthogonal polynomials (Snedecor, 1966). For details of the model used see Appendix I.

Finally a chi-square analysis (Snedecor, 1966) was carried out within each age classification to determine whether there were herd differences in S.R. and P.R.

* Manufactured by Lilley, F.J.C., 331, Charles Street Glasgow, United Kingdom and distributed in New Zealand by Wrightson NMA Limited Palmerston North

** Manufactured by Donald Presses, Masterton, New Zealand

*** Manufactured by Frank Paviour Limited, Mahara Road, Te Rapa, Hamilton, New Zealand

This mating harness consists of a small square stainless steel unit containing an exposed freely rotating steel ball that is fastened securely under the jaw of the animal by a special halter. The stainless steel unit contains a coloured paint which is released when the rotating steel ball is depressed during mating.

RESULTS

The body weight data for the five yearling herds and for the four parous cow herds are shown in Tables Xa and XIa respectively. Analyses of variance on the measurements from which these two tables have been derived are displayed in Tables Xb and XIb. Significant herd effects in the case of the yearling herds, and herd and age effects in the parous cow herds were found in respect to body weight; not expected was the significant herd x age interaction (Table XIb). This latter result can be attributed to Herd II where the mean body weights of the three year-old animals were less than those of the two year-old heifers in that herd (Table XIa).

The reproductive performance, as measured by S.R. and P.R. for the yearling heifers and for the three age groups of parous cows in the different herds, is shown in Tables XIIa and XIIIa. When chi-square analyses were carried out on these data significant herd influences on performance were found, although not consistently (see Tables XIIb and XIIIb).

The S.R. and P.R. responses for the different age groups of cattle, within each body weight classification, are shown in Table XIV, F values for the linear and quadratic components of the S.R. and P.R. responses to regression appear in Table XV.

The points of the regression line relating liveweight to both S.R. and P.R. for the different age groups of cattle have been plotted in Figures 5 to 8. On each figure the line of best fit (for method of calculation see Materials and Methods) has been drawn. Since some of the earlier analyses (Tables X - XIII) had shown clear evidence of herd effects on factors such as body weight, S.R. and P.R., the interpretations and conclusions relating liveweight with reproductive performance have been restricted to results obtained where herd effects have been removed. No comments are made on the results where herd effects have been ignored - this information has been included for comparison in Appendix II.

Although there was a positive relationship between liveweight at the beginning of mating and S.R. in the yearling heifers, with the lightest body weight group showing the poorest and the heaviest body weight group the best performance, this relationship was not significant (Fig. 5a and Table XV). The relationship between liveweight and pregnancy rate in this same age group was more convincing (Table XV- $0.05<P<0.1$ for the quadratic response) although it did not appear to be a simple linear response (see Fig. 5b).

Similar relationships were looked for in the three age groups of parous cows (Fig. 6-8) but without finding any consistent response. Thus with the two year-old group no relationship emerged between body weight taken before the first cow calved and the subsequent S.R. (Table XV and Fig. 6a) yet a distinct curvilinear relationship between body weight and pregnancy rate was found (Table XV and Fig. 6b); this latter relationship was in a reverse direction to that found for the yearling cattle. The three year-old group on the other hand showed a positive significant and linear relationship between body weight and S.R. (Table XV and Fig. 7a) but no relationship between body weight and P.R. (Table XV and Fig. 7b) while with the mature cattle there was a significant curvilinear relationship between body weight and S.R. (Table XV and Fig. 8a) and no relationship between body weight and P.R. (Table XV and Fig. 8b).

The overall performance of the yearling heifers was better in respect to both S.R. and P.R. than the performance recorded for the parous cows (Table XIV). Within the three age categories of the parous cows the two year-old animals tended to have lower S.R. than their older herd contemporaries; an exception to this was found in Herd II where a S.R. of 92% was obtained with this particular age group (Table XIIIa). Low P.R. were also noted with the two year-old age groupin Herds I and III (Table XIIIa).

TABLE Xa: MEAN BODY WEIGHTS OF THE YEARLING HEIFERS IMMEDIATELY BEFORE MATING IN FIVE HERDS(KG)

Herd	n	Mean body wt ± S.D.
I	47	238 ± 23
III	17	251 ± 22
V	14	277 ± 22
VI	20	247 ± 25
VII	86	231 ± 27

TABLE Xb: ANALYSIS OF VARIANCE FOR HERD EFFECTS ON BODY WEIGHT OF THE YEARLING HEIFERS

Source of variation	Sum of Squares	Degrees of freedom	Mean Square	F
Between herds	28679	4	7169	11.07**
Within herds	115945	179	648	

** Differences highly significant $P < 0.005$

TABLE XIa: MEAN BODY WEIGHTS OF THE DIFFERENT AGE GROUPS OF PAROUS COWS MEASURED BEFORE THE FIRST COW CALVED IN EACH HERD (KG)

Herd	Age of cow	n	Mean body wt. ± S.D.
I	2 year-old	31	416 ± 33
	3 year-old	29	452 ± 39
	Mature	131	505 ± 49
II	2 year-old	24	396 ± 48
	3 year-old	16	373 ± 44
	Mature	72	502 ± 58
III	2 year-old	25	381 ± 36
	3 year-old	16	407 ± 36
	Mature	50	451 ± 44
IV	2 year-old	19	347 ± 23
	3 year-old	19	373 ± 39
	Mature	35	485 ± 49

TABLE XIb: ANALYSIS OF VARIANCE FOR HERD AND AGE EFFECTS ON BODY WEIGHT OF THE PAROUS COWS

Source of variation	Sum of Squares	Degrees of freedom	Mean Square	F
Herd	170889	3	56963	26.68**
Age	870705	2	435353	203.89***
Herd X Age	94531	6	15755	7.39**
Residual	971528	455	2135	

** Herd and herd x age interaction highly significant $P < 0.005$

*** Age effect very highly significant $P < 0.001$

TABLE XIIa: SUBMISSION RATES (.S.R) AND PREGNANCY RATES (P.R.) FOR A FOUR-WEEK BREEDING PERIOD FOR YEARLING HEIFERS IN FIVE DAIRY HERDS

	S.R.		P.R.	
Herd	n	%	n	%
I	47	89.4	42	71.4
III	17	88.2	15	100.0
V	14	100.0	14	92.9
VI	20	95.0	19	100.0
VII	86	96.5	83	84.3

TABLE XIIb: CHI SQUARE TEST OF INDEPENDENCE FOR HERD DIFFERENCES IN SUBMISSION RATE (S.R.) AND PREGNANCY RATE (P.R.) FOR YEARLING HEIFERS USING R X C METHOD (Snedecor, 1966)

Age	Parameter	d.f.	χ^2	P
Yearling	S.R.	4	4.69	$0.25 < P < 0.5$
	P.R.	4	12.76	$0.025 < P < 0.01$

TABLE XIIIa: SUBMISSION RATES (S.R.) AND PREGNANCY RATES (P.R.) FOR A FOUR-WEEK BREEDING PERIOD FOR THREE AGE GROUPS OF PAROUS COWS IN THE FOUR DAIRY HERDS

Herd	Age	S.R.		P.R.*	
		n	%	n	%
I	2 year-old	31	38.7	12	16.7
	3 year-old	29	79.3	23	78.3
	mature	131	85.5	112	58.0
II	2 year-old	24	91.7	22	72.7
	3 year-old	16	81.3	13	69.2
	mature	72	79.2	57	70.2
III	2 year-old	25	68.0	17	35.3
	3 year-old	16	100.0	16	75.0
	mature	50	100.0	50	76.0
IV	2 year-old	19	79.0	15	73.3
	3 year-old	19	89.5	17	58.8
	mature	35	80.0	28	64.3

*P.R. is calculated only on animals submitted for service

TABLE XIIIb: CHI SQUARE TEST OF INDEPENDENCE FOR HERD DIFFERENCES IN SUBMISSION RATE (.S.R) AND PREGNANCY RATE (P.R.) WITHIN EACH AGE CLASSIFICATION USING R X C METHOD (Snedecor, 1966)

Age	Parameter	d.f.	χ^2	P
2 year-old	S.R.	3	18.33	$0.005<P<0.01$
	P.R.	3	14.52	$0.005<P<0.01$
3 year-old	S.R.	3	4.23	$0.1<P<0.25$
	P.R.	3	1.96	$0.25<P<0.5$
Mature	S.R.	3	11.83	$0.005<P<0.01$
	P.R.	3	5.73	$0.1<P<0.25$

TABLE XIV SUBMISSION RATE (S.R.) AND PREGNANCY RATE (P.R.) RESPONSES FOR THE DIFFERENT AGE GROUPS OF CATTLE WITHIN EACH WEIGHT CLASSIFICATION*

	Yearling			2 year-old			3 year-old			Mature		
Group[x]	n	S.R.%	P.R.%[+]	n	S.R.%	P.R.%	n	S.R.%	P.R.%	n	S.R.%	P.R.%
A	25	76.0	89.5	17	70.6	50.0	12	83.3	50.0	41	73.2	70.0
B	37	97.3	77.8	12	83.3	50.0	14	71.4	50.0	59	88.1	67.3
C	32	96.9	80.7	26	57.7	73.3	14	78.6	63.6	49	87.8	60.5
D	35	94.3	81.8	18	61.1	63.6	16	87.5	92.9	44	90.9	67.5
E	26	96.2	92.0	10	50.0	60.0	13	100.0	100.0	45	91.1	70.7
F	29	100.0	93.1	16	81.3	38.5	11	100.0	54.6	50	82.0	56.1
Total	184	93.5	85.8	99	67.3	55.9	80	86.8	68.5	288	85.5	65.4

* Herd effects removed from data. [+] Note P.R. is calculated only on animals submitted for service.

[x] A is lowest body weight group increasing through to highest body weight group F (see Materials and Methods)

TABLE XV: F VALUES FOR LINEAR AND QUADRATIC COMPONENTS OF THE RESPONSE TO REGRESSION (HERD EFFECTS REMOVED)

Age	Parameter	Component	F	P
	S.R.*	L (Linear)	4.55	0.1<P<0.25
Yearling		Q (Quadratic)	1.76	0.25<P<0.5
	P.R.	L	3.07	0.1<P<0.25
		Q	5.79	0.05<P<0.1
	S.R	L	0.13	P>0.5
2 year-old		Q	1.36	0.25<P<0.5
	P.R.	L	0.33	P>0.5
		Q	9.16	0.05<P<0.1
	S.R.	L	10.1	P÷0.05
3 year-old		Q	1.74	P>0.25
	P.R.	L	0.53	P>0.25
		Q	0.67	P>0.25
	S.R.	L	5.21	P÷0.1
Mature		Q	19.17	0.005<P<0.025
	P.R.	L	1.06	P>0.25
		Q	0.11	P>0.25

* S.R. = Submission rate P.R. = Pregnancy rate

Key to Figures 5a and 5b.

A = All yearlings of lower body weight than 1 S.D. below the mean for each herd (<215, <229, <255, <222 and <204 kg for herds I - VII respectively)

B = All yearlings of body weight between ½ S.D. and 1 S.D. below the individual herd means (215-226, 229-239, 255-265, 222-234 and 204-217 kg for herds I - VII respectively).

C = All yearlings of body weight between ½ S.D. below the mean and the individual herd means (227-237, 240-250, 266-276, 235-246 and 218-231 kg for herds I - VII respectively).

D = All yearlings of body weight between ½ S.D. above the mean and the individual herd means (238-248, 251-261, 277-287, 247-258 and 232-244 kg for herds I - VII respectively).

E = All yearlings of body weight between ½ S.D. and 1 S.D. above the individual herd means (249-260, 262-272, 288-298, 259-271 and 245-258 kg for herds I - VII respectively).

F = All yearlings of higher body weight than 1 S.D. above the mean for each herd (>260, >273, >299, >271 and >258 kg for herds I - VII respectively).

Figure 5a Submission rate for yearling Friesian cattle according to body weight before breeding in 5 dairy herds. (Herd effects removed)

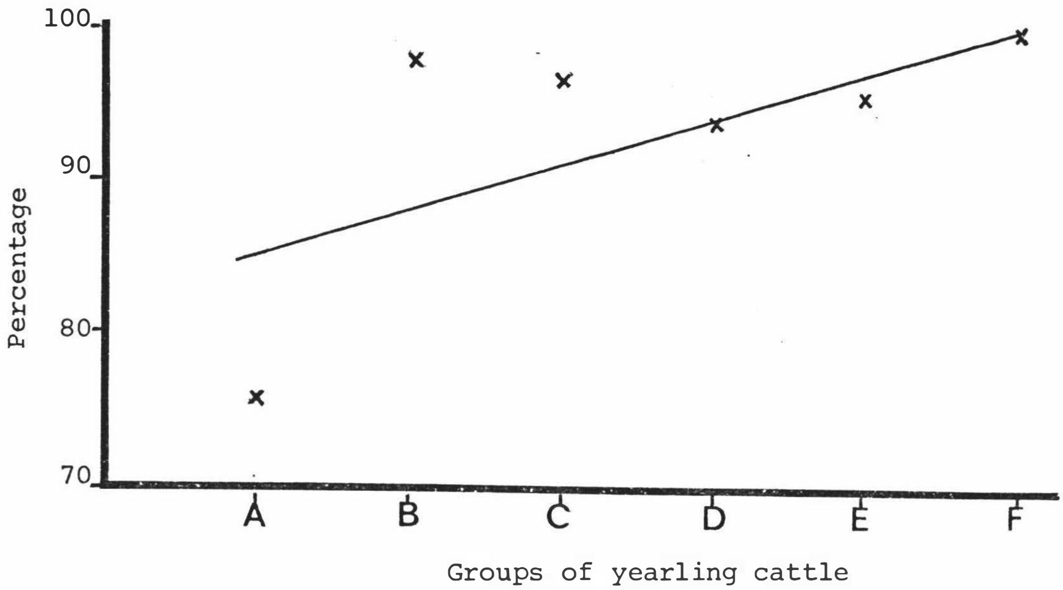
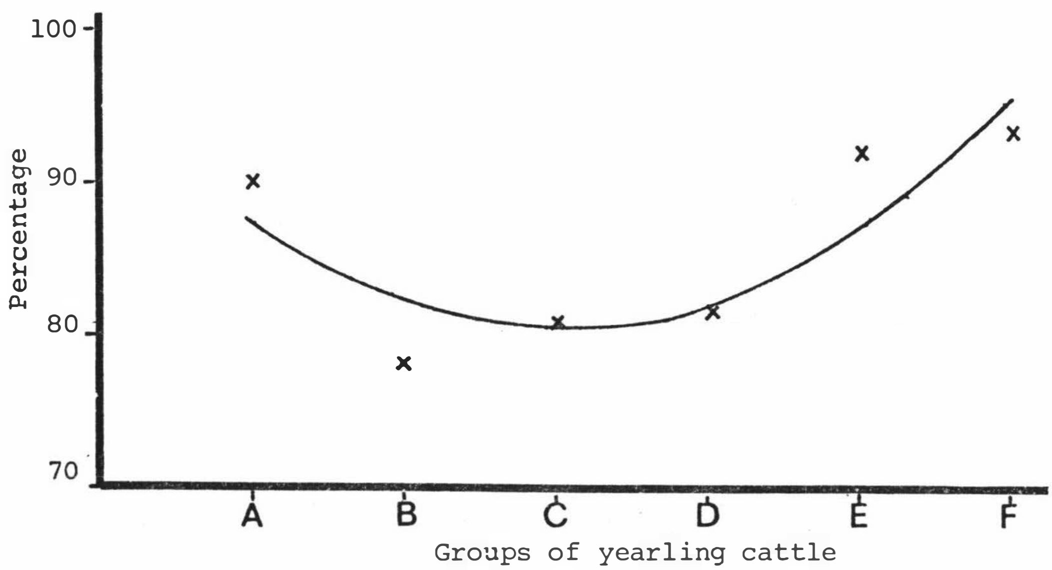


Figure 5b Pregnancy rate for yearling Friesian cattle according to body weight before breeding in 5 dairy herds. (Herd effects removed)



Key to Figures 6a and 6b

A = All 2 year-old cattle of lower body weight than 1 S.D. below the mean for each herd (<383, <348, <345 and <324 kg for herds I-IV respectively).

B = All 2 year-old cattle of body weight between ½ S.D and 1 S.D. below the individual herd means (383-399, 348-372, 345-362 and 324-335 kg for herds I-IV respectively).

C = All 2 year-old cattle of body weight between ½ S.D. below the mean and the individual herd means (400-416, 373-396 363-380 and 336-346 kg for herds I-IV respectively).

D = All 2 year-old cattle of body weight between ½ S.D. above the mean and the individual herd means (417-432, 397-420, 381-398 and 347-358 kg for herds I-IV respectively).

E = All 2 year-old cattle of body weight between ½ S.D. and 1 S.D. above the individual herd means (433-449, 421-444, 399-416 and 359-369 kg for herds I-IV respectively).

F = All 2 year-old cattle of higher body weight than 1 S.D. above the mean for each herd (>449, >444, >416 and >369 kg for herds I-IV respectively).

Figure 6a Submission rate for 2 year-old Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)

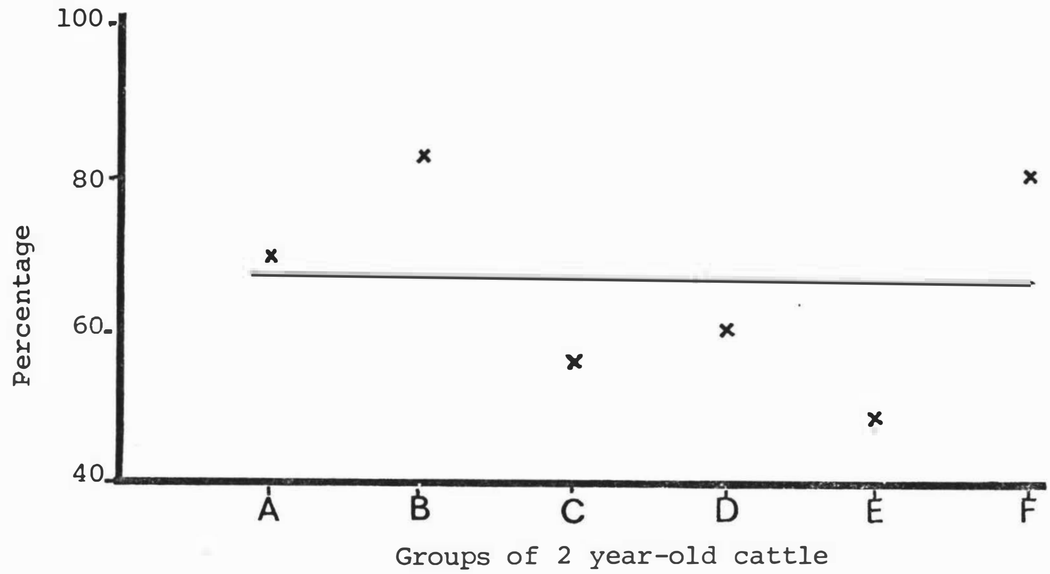
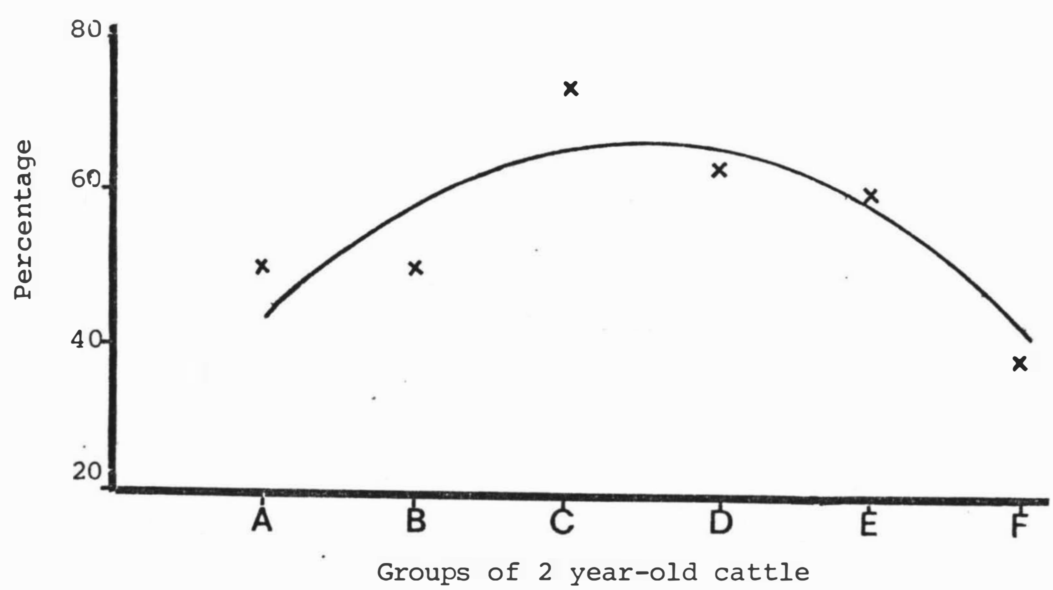


Figure 6b Pregnancy rate for 2 year-old Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)



Key to Figures 7a and 7b

A = All 3 year-old cattle of lower body weight than 1 S.D. below the mean for each herd (<412, <329, <370 and <334 kg for herds I-IV respectively).

B = All 3 year-old cattle of body weight between ½ S.D. and 1 S.D. below the individual herd means (412-431, 329-351, 370-388 and 334-353 kg for herds I-IV respectively).

C = All 3 year-old cattle of body weight between ½ S.D. below the mean and the individual herd means (432-451, 352-373, 389-406 and 354-372 kg for herds I-IV respectively).

D = All 3 year-old cattle of body weight between ½ S.D. above the mean and the individual herd means (452-471, 374-395, 407-424 and 373-392 kg for herds I-IV respectively).

E = All 3 year-old cattle of body weight between ½ S.D. and 1 S.D. above the individual herd means (472-490, 396-417, 425-442 and 393-411 kg for herds I-IV respectively).

F = All 3 year-old cattle of higher body weight than 1 S.D. above the mean for each herd (>490, >417, >442 and >411 kg for herds I-IV respectively).

Figure 7a Submission rate for 3 year-old Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)

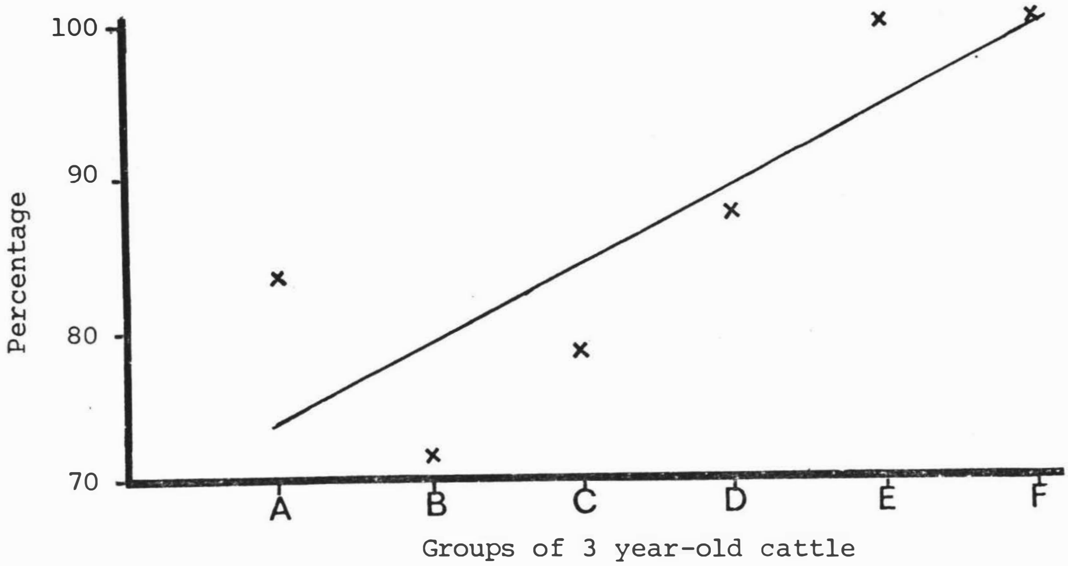
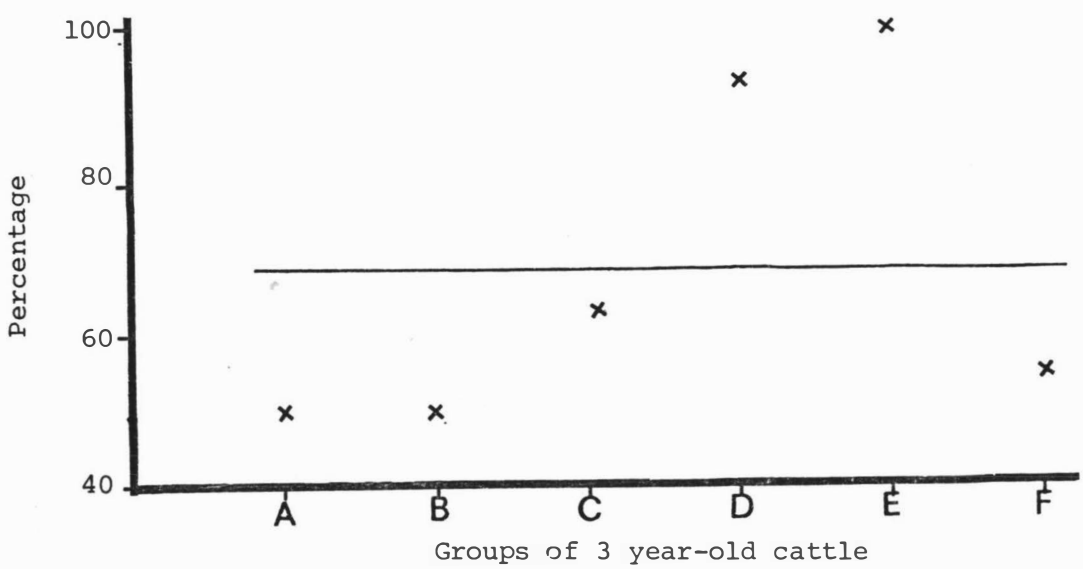


Figure 7b Pregnancy rate for 3 year-old Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)



Key to Figures 8a and 8b

A = All mature cattle of lower body weight than 1 S.D. below the mean for each herd (<456, <444, <407 and <435 kg for herds I-IV respectively).

B = All mature cattle of body weight between ½ S.D. and 1 S.D. below the individual herd means (456-480, 444-472, 407-429 and 435-460 kg for herds I-IV respectively).

C = All mature cattle of body weight between ½ S.D. below the mean and the individual herd means (481-504, 473-501, 430-451 and 461-484 kg for herds I-IV respectively).

D = All mature cattle of body weight between ½ S.D. above the mean and the individual herd means (505-529, 502-530, 452-473 and 485-509 kg for herds I-IV respectively).

E = All mature cattle of body weight between ½ S.D. and 1 S.D. above the individual herd means (530-553, 531-559, 474-495 and 510-534 kg for herds I-IV respectively).

F = All mature cattle of higher body weight than 1 S.D. above the mean for each herd (>553, >559, >495 and >534 kg for herds I-IV respectively).

Figure 8a Submission rate for mature Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)

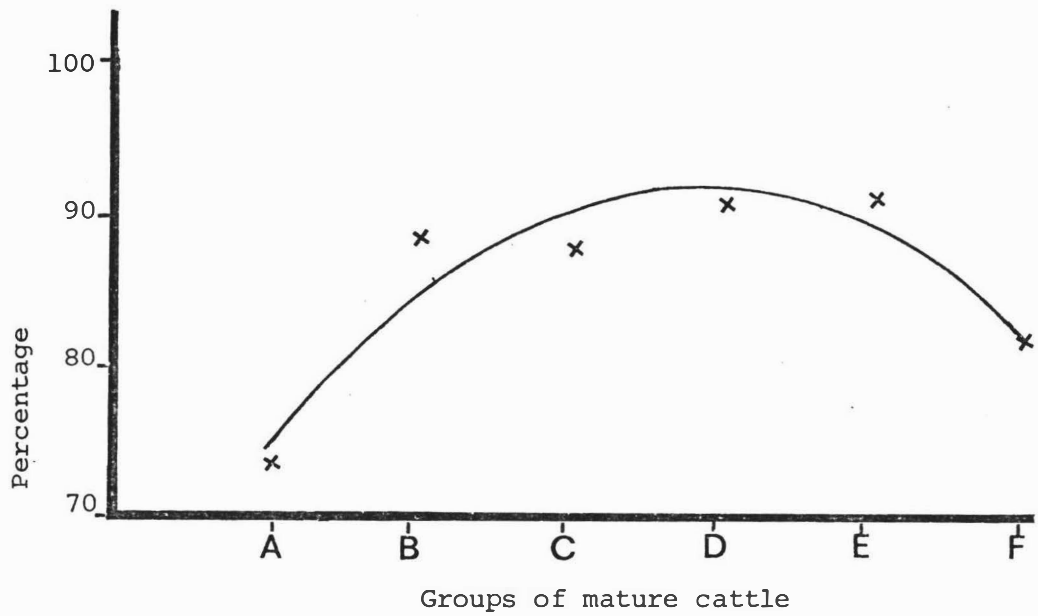
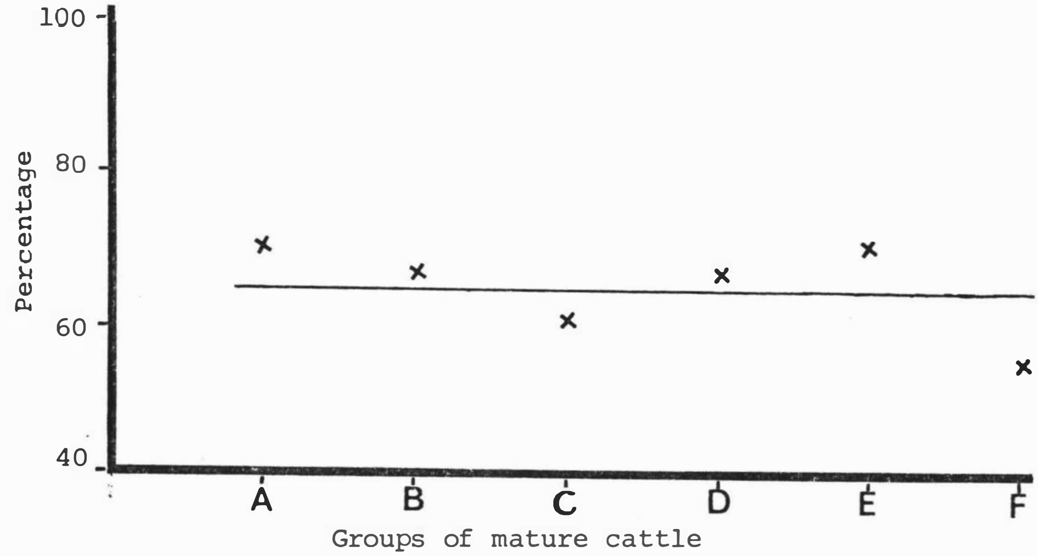


Figure 8b Pregnancy rate for mature Friesian cattle according to body weight before calving in 4 dairy herds. (Herd effects removed)



DISCUSSION

The data obtained in this study was derived from herds which were considered to have above average management but which, apart from differences in herd size, were representative of typical New Zealand seasonal supply dairy herds farming stock of predominantly the Friesian breed. A four week period for collecting information about S.R. and P.R. was selected as being sufficient for all animals experiencing oestrous cycles to have at least one heat and mating during the first four weeks of the breeding period. Similar methods of mating management were practised in all herds; A.I. was used for seven weeks of the breeding period for the parous cows and natural mating with bulls of a young age for yearling heifers.

Yearling heifers

Significant herd differences in the mean body weights of the yearling heifers were noted although the weight range for this age group within herds was remarkably consistent (S.D. between the different herds varied from 22-27 kg - see Table Xa). It is likely that management practices related to the rearing of young stock would account for these differences although minor variations between herds in breed (the amount of Jersey blood did vary slightly between herds) and age cannot be discounted as contributing factors. The age of the individual animals in the herds was not taken into account during the study since dates of birth were not always available - it was assumed that any differences that existed would be randomly distributed within the herd groups.

In general, the body weights of the heifers in the different herds were very satisfactory since the mean body weights in three out of five herds were comparable to the target mating weight for Friesians of this age set by Davey (1976) at 250 kg. Actual body weights for individuals however, ranged from 165 - 290 kg.

To obtain a 63 - 70% herd in-calf-rate over a four week breeding period requires a S.R. of 90% or more and a C.R. of over 70% according to Macmillan *et al.*(1977c). Judged by these standards the S.R. obtained in the present study for all the yearling heifers were good (88-100% - Table XIIa) and the recorded P.R. high (71 - 100% - Table XIIa). This compares favourably with the 72% calving rate for the first four weeks of mating recorded by Macmillan and Curnow (1976) for this age group.

Significant herd differences in S.R. were not observed and the high level of submissions obtained demonstrated that the majority of these heifers had reached puberty by the time the breeding period began. There were however significant between-herd differences in P.R.. While it is true that an animal has the ability to conceive once it reaches puberty successful conception depends upon the interplay of a number of physiological mechanisms and can be influenced by many factors both before and during the breeding season (Topps, 1977). Differences in bull fertility for example could readily have contributed to the variation in P.R. observed in this age group since all yearlings were bred by different sires under a natural mating system. Furthermore, those yearlings which reached puberty and began cycling regularly before the actual mating season began may have a higher conception rate than those which have either fewer cycles or reach puberty just as the breeding season begins - Morrow *et al.*(1970) have already reported that the percentage of heifers exhibiting standing oestrus increases gradually from the second through to the seventh cycle and anovulatory cycles are more frequent among first and second cycles than among subsequent cycles. A similar result was obtained by Morrow (1969b) in his earlier study. This possibility was not assessed in the investigation reported here since pre-mating heats were not recorded nor were regular examinations carried out to determine whether ovulation had occurred or not.

Although the line of best fit relating yearling body weight to S.R. was linear (Fig. 5a), and the relationship between the two parameters non-significant*, it can be seen that group A yearlings (the lightest group) had a S.R. of less than 80% while all other

* Since there were only 3 degrees of freedom available for error in the test applied the detection of a significant relationship between body weight and S.R. is difficult because of the high F value required.

groups achieved 90% and over. More animals in Group A had not yet reached puberty and/or were not showing signs of overt oestrus during the early mating period compared with their heavier herd mates. There would thus seem to be a minimum target weight to aim for at the beginning of mating if S.R. about 90% are to be achieved. In this study with Friesian yearlings this minimum weight varied from 204 kg in Herd VII to 255 kg in Herd V. In Herd V (the heaviest group) however, S.R. was 100% and even the lightest yearlings in this group did not have depressed S.R. If they are excluded then the minimum weight range for yearlings with S.R. about 90% lies between 204 and 229 kg. Such a concept is of course not new (see Lamond, 1970) and to determine target weights for Friesian heifers was one of the objectives of the present investigation. While the possibility of different 'minimum target weights' for different herds does exist, a point made also by both Hanly and Mossman (1977) and by Topps (1977) with beef heifers, differences between herds could be accounted for by uncontrolled variables such as breed, strain within a breed, and age (Axelsen and Morley, 1976; Laster *et al.*, 1976). Other environmental influences such as the level of nutrition during the rearing period may also play a role.

Irrespective of whether there are real differences between herds or not, the available data suggests that animals which are of higher liveweights at time of breeding produce better S.R. responses than those of lower liveweight. While there may be no advantages in having yearling heifers reared to reach weights above a certain minimum by the time breeding commences, body weight at mating, and factors which affect the attainment of this weight, must be regarded as important determinants of S.R. and consequently of reproductive performance.

A relationship between P.R. and body weight has not been clearly demonstrated in the present investigation. The curvilinear nature of the response obtained can be attributed to the good performance of those heifers that were submitted and became pregnant in the lowest body weight groups. If this group (Group A - Fig. 5b) is ignored, there appears to be a simple linear relationship between P.R. and body weight. Such a relationship is understandable if the heavier body weight yearling heifers experience earlier puberty and more oestrous cycles than their lighter contemporaries before they are bred.

Whether this does in fact confer a fertility advantage on maiden heifers does not appear to have been clearly demonstrated although maturation of the reproductive system continues well beyond the first heat (Swanson *et al.*, 1972) and the work of Morrow (1969b) and Morrow *et al.*,(1970) already quoted suggests that the incidence of anovulatory (infertile) cycles is highest in the immediate post-pubertal period. The relatively good performance of the Group A yearlings in this investigation remains unexplained.

Experimental evidence concerning any relationship that may exist between liveweight at mating and P.R., provided the animal is cycling, continues to be conflicting as has already been discussed in the literature review. The results of the present study shed no further light on the problem and further research is required to clarify whether such a relationship does indeed exist.

In summary the approach used in the trial reported in this thesis seems to be useful and can be readily applied with yearling heifers. Further evidence is however required to clarify whether the concept of a target weight for a breed varies between different environments (properties) and to determine what relationships exist between liveweight and pregnancy rate once puberty has been reached. Age and the influence of the number of pre-mating-season cycles on subsequent conception rates clearly need to be taken into consideration in a future investigation. Although age has only a small influence on the attainment of puberty (Joubert, 1963) this variable cannot be ignored as indicated by the report of Axelsen and Morley (1976) who noted significant age effects on oestrus - yearlings which had failed to conceive by six weeks of mating were on average 24 days younger than those that did become pregnant during this period.

Parous cows

Marked differences were found between herds in the body weights measured before the first cow in each herd calved. Time of drying-off and the level of nutrition during the dry period are likely to have been the two major factors contributing to these differences. Age differences in body weight, particularly during the period of continuing body growth, were anticipated but the emergence of an interaction between herd and age was unexpected (Table XIa). This interaction was brought about by the low body weights of the three year-old cattle in Herd II compared with the body weights of the two year-olds in this same herd. According to the herd owner, pasture growth the previous year had been poor and the two year-old animals during that period had suffered rather more severely than other animals in the herd - this effect carried over to the three year-old stage thus accounting for the low weights observed with this age group when the measurements in this herd were taken.

The body weights for the Friesian cows in the four herds studied were generally lower than the target weights set by Bryant (1977) for Friesian cows just before calving. In the two year-old cows, their mean body weights were lower than the target weights by 14 - 63 kg while the figures for three year-old and mature cows were 8 - 87 kg and 35 - 89 kg respectively. Even allowing for the weighing to calving interval of 25 days or more (Table XVII) which occurred in the present investigation this suggests that many animals were in poorer body condition than is desirable if high levels of productive and reproductive performance are to be attained.

There were marked differences between the different age groups in the four herds studied in both S.R. and P.R. (Table XIIIa). Even within herds differences in performance between ages was notable with the two year-old cows in particular (except for Herd II) performing poorly. This phenomenon of poor S.R. with two year-old cattle is consistent with the previous findings reported by Fielden *et al.*(1973) and Macmillan *et al.*(1975); a tendency for poorest results to be observed in larger herds was also noted (Macmillan *et al.* 1975). Probable reasons for this finding according to Fielden and Macmillan (1973) are those factors associated with the continued demands for growth and lactation in an age group which is likely to experience nutritional and other stresses within the herd greater than those experienced by older herd mates. Herd I was in

TABLE XVI: RELATIONSHIP BETWEEN THE POST-CALVING INTERVAL AND SUBMISSION RATES (S.R.) FOR THREE AGE GROUPS OF COWS IN FOUR DAIRY HERDS

	Period from calving to beginning of herd mating (days)								
Age	<20		21 - 40		41 - 60		>60		Total
	n	S.R.%	n	S.R.%	n	S.R.%	n	S.R.%	S.R.%
2 year-old	3	33.3	9	44.4	28	64.3	59	72.9	66.67
3 " "	8	50.0	12	75.0	21	90.5	39	94.9	86.3
Mature	15	46.7	46	76.1	66	84.8	161	92.5	85.8

TABLE XVII: WEIGHING, CALVING AND JOINING DATES AND WEIGHING TO CALVING INTERVAL FOR THREE AGE GROUPS OF COWS IN FOUR DAIRY HERDS

Herd	n	Weighing Date	Mean Calving Date	± S.D. (days)	Joining date	Mean weighing to calving interval ± S.D. (days)
I	191	26/7/76	22/8/76	± 19.5	20/10/76	27.7 ± 18.9
II	112	22/7/76	18/8/76	± 22.4	10/10/76	25.9 ± 22.5
III	91	20/7/76	15/8/76	± 13.0	22/10/76	24.7 ± 12.9
IV	73	21/7/76	22/8/76	± 19.1	20/10/76	31.1 ± 19.5

fact the largest herd in the group; the mean body weights of the parous cows in this herd were however higher than in the other herds (Table XIa) and even though the animals in Herd I had the highest percentage of pure Friesian blood, low S.R. and P.R. were observed. Herd size may have contributed to this result although it seems more likely that some other factor (or factors) which was not identified must have been operating to produce such a poor result.

The majority of the two year-old cattle in the herds studied had post-partum intervals of more than 40 days before mating began (88% of animals) with 60% having a post-partum interval before breeding of more than 60 days (see Table XVI). This may not be a long enough period however since Moller (1970) reported that two year-old cows averaged 52 days before their first post-partum ovulation and Casida and Wisnicky (cited by Roberts, 1971) noted that the first post-partum ovulation in all cows tended to occur 25.4 days earlier than the first post-partum overt heat. Post-partum period thus appears to be critically related to the occurrence of the first post-partum oestrus in this age group - about half of the two year-old cows that were not submitted during this study had post-partum periods of more than 60 days when breeding began and Fielden *et al.* (1973) in an earlier study had found that lack of cyclical activity was a major cause of low S.R. in two year-old cattle even though they had post-partum intervals of 60 days or more at the time of examination. The influence of the period from calving to the beginning of mating on subsequent S.R. is clearly illustrated for all ages in Table XVI.

While a high S.R. is of utmost importance in achieving a concentrated calving in a herd an early return to cyclical activity after calving is likely to confer other advantages such as an improvement in the pregnancy rate obtained during the first month of breeding. Animals which have experienced one open heat or more before they are bred have a higher pregnancy rate when mated than do animals of comparable post-partum interval which are bred at their first observed heat (Whitemore *et al.* 1974). This phenomenon probably contributes to the poorer P.R. observed over all the two year-olds in this investigation when compared with the older age groups. The latter had higher S.R. and probably more open heats than the younger animals (P.R. was 53%, 71% and 65% for the two year-old, three year-old and mature animals respectively).

The performance of the three year-old cows in respect to both S.R. and P.R. was generally satisfactory (Table XIIIa) and it seems clear that this age group does not suffer so seriously as the younger cows from problems delaying return to cyclical activity during the post-partum period. The mature cows in these herds similarly performed at levels which were not greatly below those set by Moller (see Fielden *et al.* 1976) following his planned animal health and production service study carried out on Waikato herds. The overall average of 83.1% S.R. for all cows in the four herds studied, while by no means optimal, is comparable to the 83.5% reported by Macmillan and Watson (1973). The 65.3% P.R. which was obtained over the first four weeks of mating for all the cows in these herds, which represents a four week herd-in-calf rate of 54.3% (83.1% S.R. x 65.3% P.R.) is comparable to the result obtained with both average S.R. and C.R. reported by Macmillan and Watson (1973).

At the outset of this trial it had been hoped that a practical method would be found to help farmers assess whether their stock were in adequate body condition before calving so that good production and high reproductive performance in the following breeding period would follow. Such a concept implies that there is a relationship between body condition (weight) before calving and reproductive performance, an implication which could be generally but not unequivocally derived from literature reviewed. The results of the present trial do nothing to resolve this issue since poor and/or inconsistent relationships were recorded between body weight and both S.R. and P.R. in all three age groups of parous cows studied.

In retrospect the objective of finding a practicable method (one weighing of all cows just before the first cow calved in each herd) resulted in a major variable emerging which was not taken into consideration when analysing the data - this variable included the differences in the weighing to calving interval for individual animals both within and between herds. There were also some differences between herds in joining dates which could have had some influence on the average post-partum period before breeding in each herd. These differences have been summarised in Table XVII.

The body weight of cows may change markedly according to alterations in food intake and increasing foetal size particularly during the last month of pregnancy (Forbes, 1970) and weights taken during this period will differ depending on the length of this interval. A method which results in one weighing of all cows in the herd before the first cow calves in that herd will only really be representative of those animals which calve in the next day or two after the measurement is taken. If each cow had been weighed just prior to her due calving date (not a practical field method under normal New Zealand farming conditions) the ranking order of the cows in terms of body weight at this point of time may have been different from that recorded in this study. This, together with the differences noted in post-partum period both within and between herds (Table XVI), could easily have obscured any relationship between body weight and the two reproductive parameters studied.

A further investigation, with a much closer control of the variables either by using different methods of measurement or establishing correction factors, is needed to clarify the nature and extent of such relationships. Furthermore body condition, in conjunction with skeletal size and body weight, should be taken into consideration since weight alone may not accurately measure the 'fitness' of the animal for future reproductive performance.

CONCLUSIONS

1. A survey of the literature and results obtained in this study both point to a positive relationship between body weight and reproductive performance in maiden heifers. The most important contributing factor appears to be earlier initiation of cyclical activity (puberty) in the heavier animals. Once cyclical activity has been initiated however, it is not clear whether heavier animals have any additional advantage as far as fertility (pregnancy rate) during the initial part of the breeding season is concerned. Since this is an important issue a further investigation should be planned to resolve the question.

2. For heifers containing 75% or more of Friesian blood, and intended to be bred at about fifteen months of age, a minimum liveweight before mating of 204-229 kg should be the aim. Whether this minimum weight using a similar breed and age of animal differs between properties remains unresolved. Furthermore, productive as well as reproductive performance over the lifetime of the animal needs to be taken into consideration before a final decision can be made as to the critical minimum weight at first mating.

3. Measuring the body weight of maiden heifers as carried out in this investigation is a satisfactory farm method for determining whether maiden heifers are adequately developed for efficient breeding or not. More than one measurement from weaning through to the commencement of breeding seems to be desirable however if management decisions designed to assist all animals to reach the minimum target are to be carried out. Comparisons with other method of estimating size and condition (use of weigh bands, condidion scoring), which could be even easier to carry out, need to be made.

4. The weight of evidence from the literature read, while suggesting a relationship between liveweight and reproductive performance in parous cows similar to that for maiden heifers, is by no means totally convincing.

Results obtained in this trial do little to clarify the issue since the method used, while reasonably convenient from the farmers' point of view, results in too many variables that cannot be readily controlled. Any relationship that existed between liveweight just before calving and subsequent reproductive performance could have been obscured because of this; modifications to the approach used are required if valid answers raised are to result.

5. Despite these limitations two year-old heifers, undergoing their first lactation, continue to stand out as the potential problem group. Continued attention must be paid to their management needs if high submission and pregnancy rates are to be achieved in the first four weeks of the breeding season.

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APPENDICES

APPENDIX 1: COEFFICIENTS AND DIVISORS FOR SETS OF ORTHOGONAL COMPARISONS IN REGRESSION

Degree of polynomial	Comparison	Coefficients for 6 treatments						Divisors
2	Linear	-5	-3	-1	+1	+3	+5	70
	Quadratic	+5	-1	-4	-4	-1	+5	84

The step by step calculation of the model was as follows:-

1. Mean square for linear response of the dependent variates with 1 d.f.

$$= \Sigma Y_i \lambda_i / \Sigma \lambda_i^2 \quad \text{--------------------------------A}$$

where Y_i = either submission or pregnancy percentage

λ_i = orthogonal coefficients (linear values)

$\Sigma\lambda_i^2$ = divisor (linear value)

i = 1 ....n and n = number of observed values

2. Mean square for quadratic response of the dependent variates with 1 d.f. $= \Sigma Y_i \lambda_i / \Sigma \lambda_i^2$ ----------------------------------B

where λ_i = orthogonal coefficients (quadratic values)

$\Sigma\lambda^2_i$ = divisor (quadratic value)

3. Sum of squares for linear plus quadratic response of the dependent variates with 2 d.f. = A + B ----------------------------C

4. Total sum of squares for dependent variates with 5 d.f.

$$= \Sigma Y_i^2 - (\Sigma Y_i)^2/n \quad \text{-----------------------------D}$$

5. Residual sum of squares (error term) with 3 d.f.

$$= D - C \quad \text{-----------------------------E}$$

6. Residual mean square with 3 d.f.

$$= E / 3$$

7. F Value for Linear response = A / Residual mean square
   and for Quadratic response = B/ Residual mean square

8. Regression coefficient for response with x scale coded is given by

   $$\Sigma Y_i \lambda_i / \Sigma \lambda_i^2$$

   where the λ_i come from either the first row for the linear response or the second row for the quadratic response.

To find the best fitting line for plotting the graph, the desired values of Y were derived by adding the mean of the observed values of Y to the products of the regression coefficients and the orthogonal coefficients of the response with significant F values. In cases where there was a linear and quadratic effect ($P < 0.25$), the sum of the products of the regression coefficients and the orthogonal coefficients of both responses were used. When there was no significant relationship, the mean was used to plot the graph.

APPENDIX IIa: SUBMISSION RATE (.S.R) AND PREGNANCY RATE (P.R.) RESPONSES FOR THE DIFFERENT AGE GROUPS OF CATTLE WITHIN EACH WEIGHT CLASSIFICATION*

	Yearling			2 year-old			3 year-old			Mature		
Group[x]	n	S.R.%	P.R.%[+]	n	S.R.%	P.R.%	n	S.R.%	P.R.%	n	S.R.%	P.R.%
A	29	82.8	87.5	16	75.0	75.0	18	83.3	53.3	45	77.8	77.1
B	31	93.4	72.4	13	84.6	45.5	7	71.4	60.0	50	90.0	66.7
C	33	97.0	80.7	22	77.3	70.6	16	93.8	73.3	57	82.5	72.3
D	34	94.1	84.4	18	50.0	44.4	8	62.5	80.0	37	97.3	61.1
E	28	96.4	96.3	18	61.1	45.5	21	90.5	73.7	52	88.5	60.9
F	29	100.0	93.1	12	50.0	33.3	10	100.0	90.0	47	80.9	52.6
Total		94.0	85.7		66.3	52.4		83.6	71.7		86.2	65.1

* Herd effects ignored from data. [+]Note P.R. is calculated only on animals submitted for service

[x] A is lowest body weight group increasing through to highest body weight group F (see Materials and Methods)

APPENDIX IIb: F VALUES FOR LINEAR AND QUADRATIC COMPONENTS OF THE RESPONSE TO REGRESSION (HERD EFFECTS IGNORED)

Age	Parameter	Component	F	P
Yearling	S.R.*	L (Linear)	9.85	$0.025<P<0.1$
		Q (Quadratic)	1.59	$P>0.25$
	P.R.	L	2.94	$0.1<P<0.25$
		Q	1.26	$P>0.25$
2 year-old	S.R.	L	5.75	$0.05<P<0.1$
		Q	0.09	$P>0.5$
	P.R.	L	4.07	$0.1<P<0.25$
		Q	0.01	$P>0.5$
3 year-old	S.R.	L	0.8	$P>0.5$
		Q	0.94	$P>0.5$
	P.R.	L	23.7	$0.005<P<0.025$
		Q	0.79	$P>0.25$
Mature	S.R.	L	0.03	$P>0.5$
		Q	4.11	$0.1<P<0.25$
	P.R.	L	16.11	$0.025<P<0.1$
		Q	0.09	$P>0.5$

* S.R. = Submission rate P.R. = Pregnancy rate

Key to Appendix II c

A = All yearlings of lower body weight than 1 S.D. below the mean for the pooled herd (<212 kg).

B = All yearlings of body weight between ½ S.D. and 1 S.D. below the herd mean (212-22 kg).

C = All yearlings of body weight between ½ S.D. below the mean and the herd mean (226-239 kg).

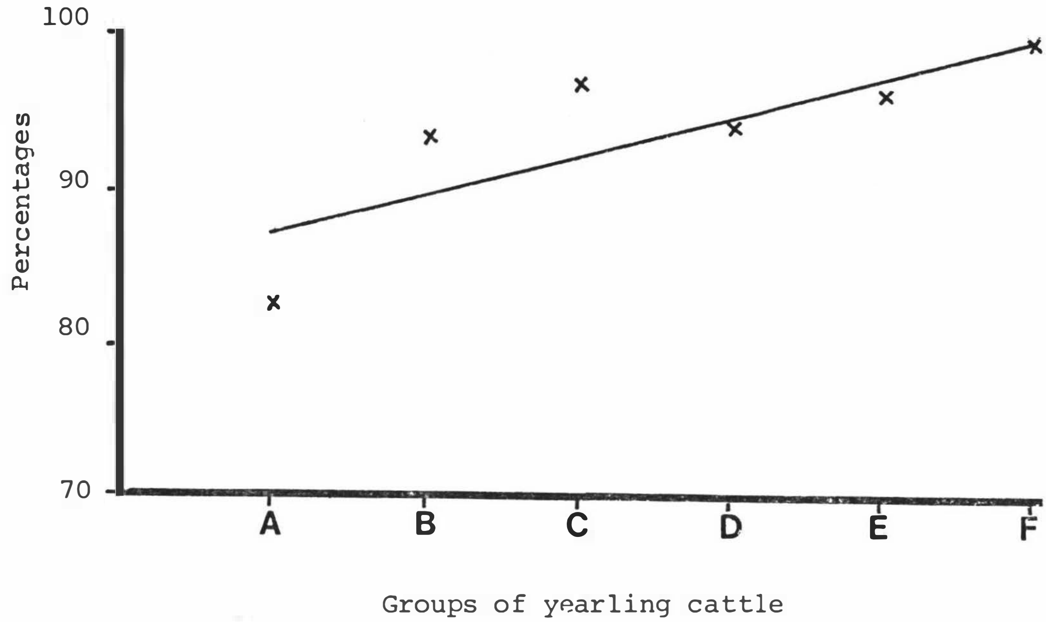
D = All yearlings of body weight between ½ S.D. above the mean and the herd mean (240-253 kg).

E = All yearlings of body weight between ½ S.D. and 1 S.D. above the herd mean (254-267 kg).

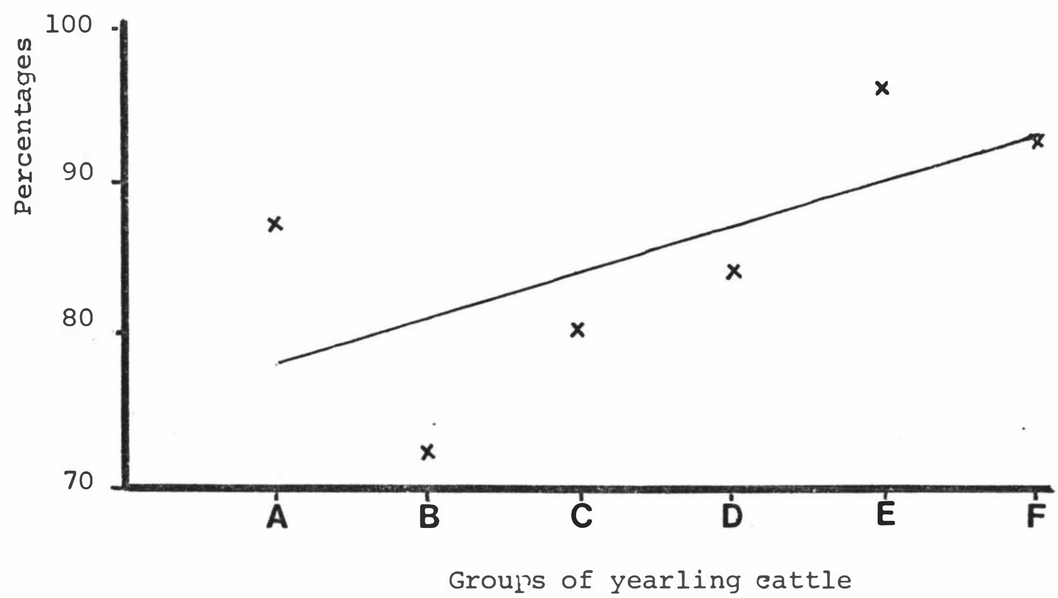
F = All yearlings of higher body weight than 1 S.D. above the herd mean (>267 kg).

APPENDIX IIc

Submission rate for yearling Friesian cattle according to body weight before breeding in 5 dairy herds. (Herd effects ignored).



Pregnancy rate for yearling Friesian cattle according to body weight before breeding in 5 dairy herds. (Herd effects ignored).



Key to Appendix II d

A = All 2 year-old cattle of lower body weight than 1 S.D. below the mean for the pooled herd (<345 kg).

B = All 2 year-old cattle of body weight between ½ S.D. and 1 S.D. below the herd mean (345-366 kg).

C = All 2 year-old cattle of body weight between ½ S.D. below the mean and the herd mean (367-388 kg).

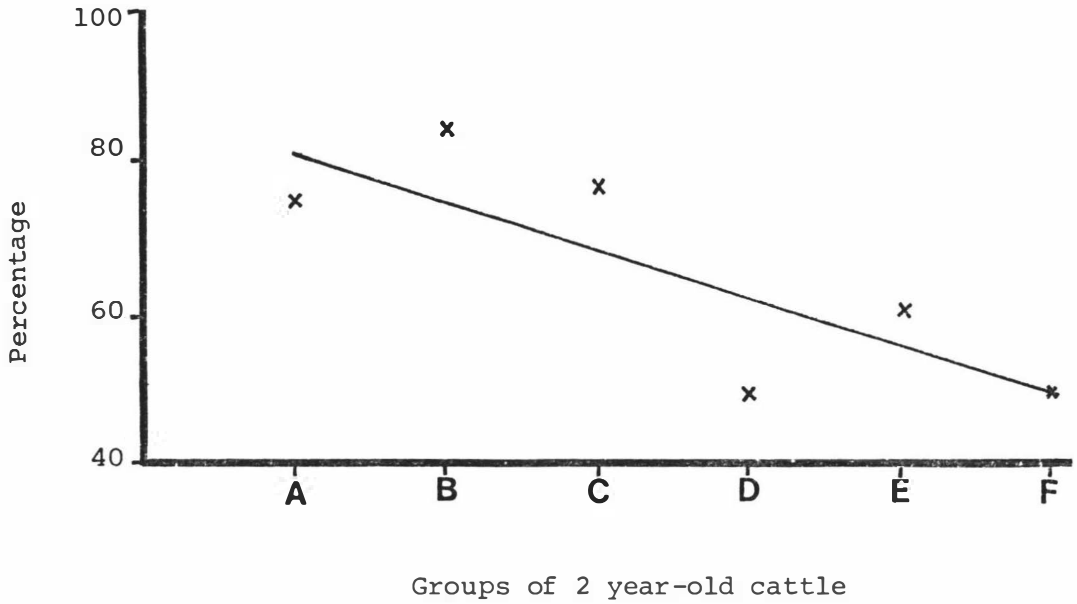
D = All 2 year-old cattle of body weight between ½ S.D. above the mean and the herd mean (389-410 kg).

E = All 2 year-old cattle of body weight between ½ S.D. and 1 S.D. above the herd mean (411-432 kg).

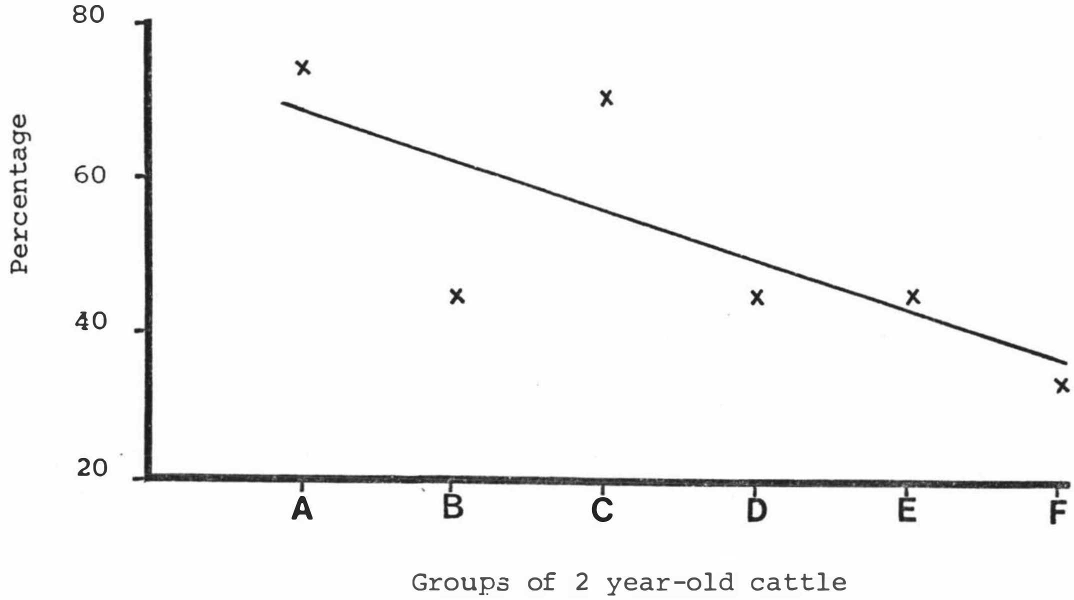
F = All 2 year-old cattle of higher body weight than 1 S.D. above the herd mean (>432 kg).

APPENDIX IId

Submission rate for 2 year-old Friesian cattle according to body weight before calving in 4 dairy herds.
(Herd effects ignored)



Pregnancy rate for 2 year-old Friesian cattle according to weight before calving in 4 dairy herds.
(Herd effects ignored)



Key to Appendix II e

A = All 3 year-old cattle of lower body weight than 1 S.D. below the mean for the pooled herd (<355 kg).

B = All 3 year-old cattle of body weight between ½ S.D. and 1 S.D. below the herd mean (355-381 kg).

C = All 3 year-old cattle of body weight between ½ S.D. below the mean and the herd mean (382-408 kg).

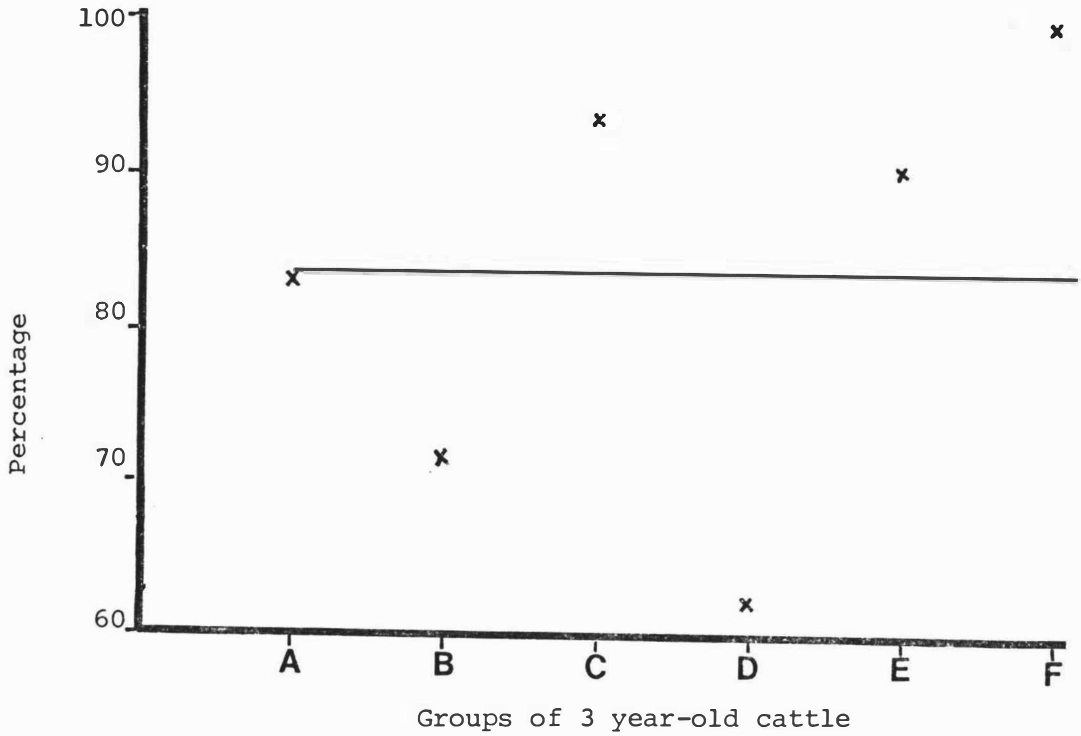
D = All 3 year-old cattle of body weight between ½ S.D. above the mean and the herd mean (409-434 kg).

E = All 3 year-old cattle of body weight between ½ S.D. and 1 S.D. above the herd mean (435-461 kg).

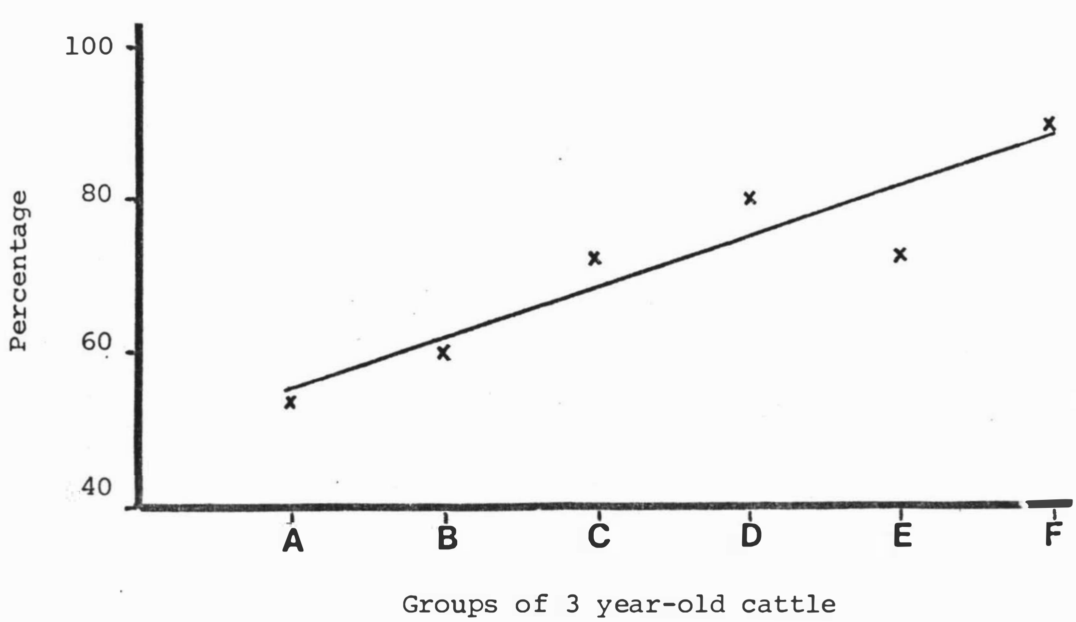
F = All 3 year-old cattle of higher body weight than 1 S.D. above the herd mean (>461 kg).

APPENDIX IIe

Submission rate for 3 year-old Friesian cattle according to body weight before calving in 4 dairy herds.
(Herd effects ignored)



Pregnancy rate for 3 year-old Friesian cattle according to body weight before calving in 4 dairy herds.
(Herd effects ignored)



Key to Appendix II f

A = All mature cattle of lower body weight than 1 S.D. below the mean for the pooled herd (<438 kg)

B = All mature cattle of body weight between ½ S.D. and 1 S.D. below the herd mean (438-465 kg).

C = All mature cattle of body weight between ½ S.D. below the mean and the herd mean (466-492 kg).

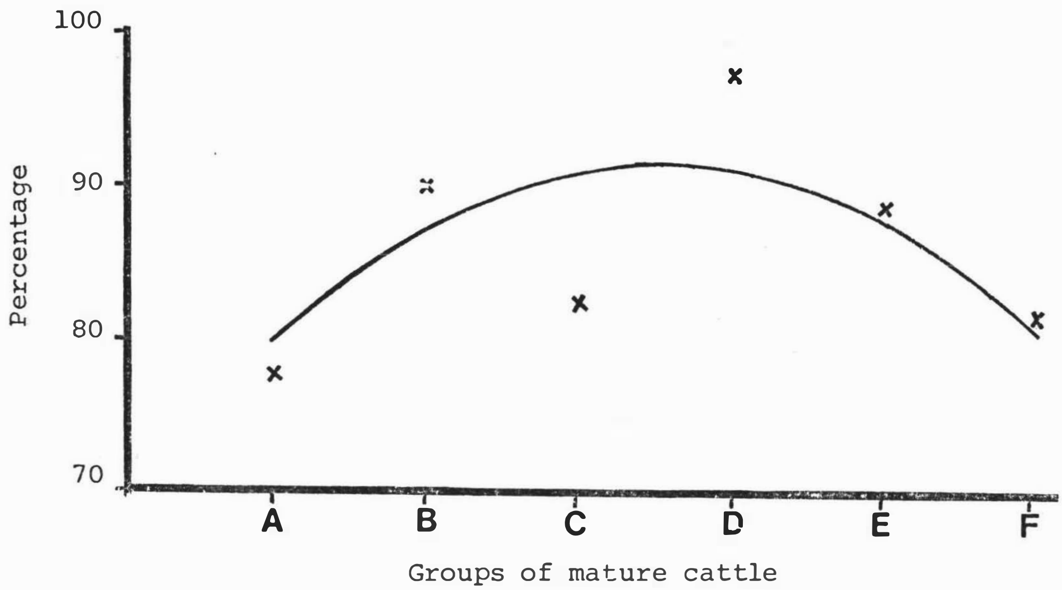
D = All mature cattle of body weight between ½ S.D. above the mean and the herd mean (493-519 kg).

E = All mature cattle of body weight between ½ S.D. and 1 S.D. above the herd mean (520-546 kg).

F = All mature cattle of higher body weight than 1 S.D. above the herd mean (>546 kg).

APPENDIX IIf

Submission rate for mature Friesian cattle according to body weight before calving in 4 dairy herds.
(Herd effects ignored)



Pregnancy rate for mature Friesian cattle according to body weight before calving in 4 dairy herds.
(Herd effects ignored)