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FACTORS INFLUENCING CONCEPTION RATES TO ARTIFICIAL BREEDING IN NEW ZEALAND DAIRY HERDS: A REVIEW

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SUMMARY

Results of analyses of data from a large insemination service and several large-scale field trials are reviewed.

Significant sire differences in fertility, as reflected by conception rate (CR), largely arise through differences in post-insemination sperm survival. These CR and survival differences cannot be reduced by doubling the sperm dose rate per insemination. CRs with sires of below average fertility are low when cows are inseminated in early oestrus. With semen from sires of above average fertility, CRs were similar when cows were inseminated in early versus late oestrus.

Significant CR differences between regions are not due to cow-fertility differences but rather arise from subtle differences in the attitude of the herd owners towards oestrus detection. A sire's average CR relative to the regional average CR is also influenced by these differences in attitude.

While herd differences in CR largely arise through differences in the owners' abilities to identify oestrous cows, errors in diagnosis are less undesirable in terms of a herd's conception pattern than errors in identification or omission.

Changes in semen processing or herd management which result in improved CRs will tend to concentrate herd calving patterns and reduce the variation in calving interval but not the mean calving interval.

Under New Zealand conditions, where the maintenance of a seasonally concentrated calving pattern is an essential requirement, obtaining a high herd submission rate is important (Macmillan and Watson, 1974), even if obtaining it means that some non-oestrous cows may be inseminated (Macmillan and Watson, 1975c, 1976). Many New Zealand farmers who use artificial breeding (AB) may have consciously or unconsciously reached this decision and therefore have realized that some mistakes in oestrus detection must be accepted. This acceptance has meant that the major factors influencing conception rates (CRs) in AB herds are on-farm or "artificial environmental" factors. Because of the interactions between physiological factors and the environmental factors associated with the use of AB, it is not surprising that after each first insemination there are 11 possible outcomes (Macmillan *et al.*, 1977b).

SEMEN AND SIRE EFFECTS

The initial effect of improvements in semen processing is that CRs for almost all sires will be increased (Shannon, 1968, 1978). Eventually these improvements will mean that CRs to AB are at least equal to those obtained with natural mating (Macmillan *et al.*, 1977b). Further improvements will tend to reduce between-sire variation in their average CRs (Macmillan and Watson, 1975e). While the CRs for bulls of below average fertility can increase through improved semen processing, the bulls of above average fertility will have further CR improvement restricted by factors other than those caused by semen or sperm factors. At this point the tendency will be to reduce the sperm dose rate per insemination (Shannon, 1968), thus increasing selection pressure and obtaining more inseminations per sire but using fewer sires (Stichbury, 1968). The standard insemination dose rate is now 2 million total sperm (Macmillan and Hart, 1977). Such low dose rates are essential to fulfilling the marked seasonal pattern in semen demand (Macmillan and Curnow, 1976b) while still obtaining a satisfactory number of inseminations per sire. These low sperm dose rates do not increase the variation in CRs obtained by individual inseminators, and increasing dose rate by 50% did not reduce between-inseminator variation. Neither did a 100% increase in sperm dose rate affect CRs (Macmillan and Watson, 1977).

While improvements in semen processing have resulted in reductions in sperm dose rates per insemination, significant sire differences in CR still remain (Macmillan and Watson, 1975b). These differences arise becase of a significant interaction involving the stage of oestrus at insemination (Macmillan, 1973; Macmillan and Watson, 1975e), with greatest between-sire variation being found with early-oestrus inseminations and least variation with post-oestrus inseminations. More recent trials have shown that, whereas with sires of below average fertility best CR results are obtained with late- or post-oestrus inseminations, with high fertility sires it may be preferable to inseminate before mid-oestrus (Macmillan and Curnow, 1977b) (Table 1).

This interaction between sire fertility and stage of oestrus at insemination most probably involves sperm survival within the uterus. Macmillan and Curnow (1977b) found that if dose rate was reduced from 2.5 million to 0.5 million sperm per insemination, the overall CR change of 7.2% was the result of an 8.8% decline in the CR for early/mid-oestrus inseminations and a 5.4% decline for late/post-oestrus inseminations (Table 1).

TABLE 1: INTERACTIONS IN CONCEPTION RATE RESULTING FROM SIRE FERTILITY AND SPERM DOSE RATE WITH STAGE OF OESTRUS AT INSEMINATION

	All Insem.	*Early Insem.*	*Late Insem.*
Sire fertility			
Below average	59.5	57.1	61.9
Average	64.5	63.8	65.3
Above average	68.5	69.0	67.9
Sperm dose rate			
2.5 ($\times$ 10^6/insem.)	64.0	62.0	65.9
0.5 ($\times$ 10^6/insem.)	56.8	53.2	60.5

The stage of oestrus at insemination can also result in CR interactions involving deep-frozen semen and liquid semen (Macmillan and Curnow, 1977a), indicating that reasonable increases in sperm dose rate will not compensate for differences in *in utero* sperm survival. Since the greatest CR differences between sires and between methods of semen processing involve early/mid-oestrus inseminations, the common overseas recommendation to delay the time of insemination following the initial diagnosis of oestrus (Salisbury and Van Demark, 1961) is justified in situations where semen processing is compromising fertility or bulls are of below average fertility. It is possible that the widespread adoption of this recommendation has restricted the rate of progress which could have been made in semen processing, particularly with deep-frozen semen.

INSEMINATOR AND ENVIRONMENTAL EFFECTS

Many inseminators are the "victims of circumstance", their results being significantly influenced by the management practices of the owners of the herds in which they inseminate cows (Macmillan, 1975). These factors notwithstanding, there are significant differences in the CR results obtained by individual technicians, and in many cases the cause cannot be determined. Low sperm dose rates per insemination do not contribute to these differences (Macmillan and Watson, 1977). With the routine use of such sperm dose rates, intra-uterine deposition of the semen is essential, as deep cervical deposition will definitely reduce CRs (Moller *et al.*, 1972).

A most striking feature of CR data for New Zealand herds is the large and significant differences in the average CRs in each season between the six Livestock Improvement Associations (LIAs) (Macmillan and Watson, 1975a). The largest differences (average = 6.3%) arose between the Taranaki (T) and Wellington-Hawke's Bay (W) LIAs, even though both LIAs were supplied with liquid semen from the same sires. In the W LIA, return inseminations were not charged for, and consequently herd owners in this LIA were more likely to submit a cow for insemination even if they had doubts as to whether or not she was in oestrus. Consequently, the incidence of errors in oestrus detection and short return intervals was higher in the W LIA than in the T LIA. This difference in herd-owner attitude also meant that more cows were inseminated in early oestrus in the W LIA than in the T LIA, but there were more post-oestrus inseminations in the T LIA (Macmillan and Curnow, 1977b). This difference in submission pattern when related to sire differences in fertility resulted in an interaction between sire effects on CR and environmental (or LIA) effects on CR. These are described in the next section. None of the between-LIA differences in CR has been found to be due to differences in cow fertility or inseminator competence.

Even within a LIA within a particular season, artificial "environmental" factors can produce what appear to be seasonal trends in fertility. For example, Macmillan and Curnow (1977a) found that 79% of the 0.11% CR increase per day between October 1 and December 14 in the W LIA was due to reductions in short and long return intervals arising through a progressive reduction in the proportion of errors in oestrus detection and an increasing incidence of unrecorded long return intervals. Dramatic increases in CR of over 5% have occurred within a 3-day period in some seasons in some LIAs (P. Shannon, pers. comm.). These within-season trends in CR contribute more to the variation in CR for an individual batch of semen than variation arising from sire differences, binomial variation or random variation (Macmillan and Curnow, 1977b).

The proportion of short, long and normal return intervals can also vary between breeds of sires and between results for first and second inseminations (Macmillan and Watson, 1975b; Macmillan and Curnow, 1977b). Therefore, CR differences among different breeds of sires and between first and second inseminations are due to environmental rather than physiological factors.

INTERACTIONS BETWEEN ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS

The nature of these differences in submission patterns between LIAs must be realized when using CRs to study physiological factors which may influence fertility. Thus, although the correlation coefficient between average CRs for sires used extensively in two LIAs was 0.94, the slope of the regression line was such that, with sires of above average fertility, the CR differences were less than with sires of below average fertility (Macmillan and Curnow, 1977b). These differences are also found among CRs for individual batches of semen used on the same day in two LIAs (Table 2) and for a single batch of semen when used for first or second inseminations in the one LIA (Table 3).

TABLE 2: RELATIONSHIP BETWEEN CONCEPTION RATES (49 DAY NON-RETURN RATE) FOR 71 BATCHES OF SEMEN OF VARYING FERTILITY USED ON THE SAME DATES IN TWO LIAs

		Conception Rate (%)				*Mean*
Wellington-Hawke's Bay	(W)	50	60	65	70	60.2
Taranaki	(T)	62.8	68.2	70.9	73.5	68.3
W—T		—12.8	—8.2	—5.9	—3.5	—8.1

$T = 0.54\ W + 35.79\ (r = 0.81)$

TABLE 3: RELATIONSHIP BETWEEN CONCEPTION RATES FOR 56 BATCHES OF SEMEN OF VARYING FERTILITY USED ON THE SAME DATES FOR FIRST OR SECOND INSEMINATIONS IN THE WELLINGTON-HAWKE'S BAY LIA

	Conception Rate (%)				*Mean*
1st insemination	50	55	60	65	61.3
2nd insemination	55.8	59.8	63.8	67.8	64.9
1st—2nd	—5.8	—4.8	—3.8	—2.8	—3.6

$2\text{nd CR} = 0.80 \times 1\text{st CR} + 15.82\ (r = 0.88)$

These interactions arise because of differences first in the incidence of errors in oestrus detection resulting in non-oestrous inseminations; secondly because of the proportions of early- or post-oestrus inseminations; and finally because of the incidence of genuine short oestrous cycles (Macmillan and Watson, 1971). The incidences of errors in oestrus detection, early-oestrus inseminations and genuine short oestrous cycles all decline from September to December. Genuine short oestrous cycles of 8 to 10 days are sufficiently frequent following first inseminations that their incidence can be calculated from data for return intervals, but their presence after second inseminations, using comparable data, is imperceptible (Macmillan, 1970; Macmillan *et al.*, 1977a).

HERD DIFFERENCES AND BREEDING MANAGEMENT

There are significant CR differences between herds, and these differences largely occur because of differences in the ability of herd owners to accurately diagnose oestrus (Macmillan, 1975). A reduction in the incidence of errors in oestrus detection will certainly improve CRs, but if this reduction is associated with a reduced submission rate, the net effect may not be an increased concentration in the conception and calving patterns (Macmillan and Watson, 1974). This is because the CR among cows which herd owners considered were only showing weak symptoms of oestrus (these cows may not have been in oestrus) was 53%, compared with 67% for cows which these same herd owners were certain were in oestrus (Macmillan and Watson, 1976). Certainly, techniques for oestrus detection such as tail painting (Macmillan and Curnow, 1977c) should improve accuracy in oestrus diagnosis, but herd owners should continue to submit those cows not previously inseminated which may possibly be in oestrus.

There are three main categories of errors in oestrus detection, and while a complete elimination of all errors is a desirable objective, errors in detection arising from a liberal interpretation of symptoms of oestrus (errors in diagnosis) are less undesirable than errors in cow identification or errors of omission (which occur when oestrous cows remain undetected) (Macmillan, 1976). It has been estimated that each "error of omission" costs $36 because conception and the calving date in the following season are delayed by 3 weeks (Macmillan, 1979).

Errors in oestrus detection will naturally result in non-oestrous inseminations. But if the non-oestrous insemination precedes the oestrous insemination, then it does not reduce chances of conception to the latter insemination (Macmillan and Fielden, 1970; Macmillan, *et al.*, 1977a). In contrast, a non-oestrous second insemination made within 3 weeks of an oestrous first insemination will dramatically reduce the pregnancy rate for the oestrous first insemination (Macmillan, *et al.*, 1977a). The incidence of this undesirable sequence is not great and could be further reduced if herd owners used a simple mark on their records to indicate which cows they thought might not have been in oestrus when submitted for their first insemination (Macmillan *et al.*, 1977a).

COW FERTILITY

While 2-year-old heifers have a lower CR to first insemination than their older herd mates (64.3% vs. 68.0%), this difference is partly due to the incidence of short return intervals (Macmillan and Watson, 1975d). This higher incidence of short return intervals is associated with more genuine short oestrous cycles in these younger animals (Macmillan and Watson, 1971) and will be a reflection of more of them being inseminated at their first post-partum oestrus because of a longer period of post-partum anoestrum (Moller, 1970).

The reproductive efficiency of New Zealand's dairy cows is very high. Sixty percent of cows retained in the herd from one season to the next calve within 4 weeks of when calving was planned to commence (Macmillan and Curnow, 1976a); the average calving interval is 364 days (Macmillan and Moller, 1977); and the herd wastage rate, which was around 21% (Macmillan and Murray, 1974), is steadily declining. Any changes in management resulting in increased chances of conception to first insemination will not reduce calving interval but will reduce the variation (standard deviation = 31 days; Macmillan and Moller, 1977). It will also alter the mean calving date unless the date for the commencement of mating is adjusted (Macmillan, 1979).

It is possible that cow fertility can be improved. Macmillan and Smith (1978) and Smith and Macmillan (1978) found that if cows were injected with a prostaglandin during dioestrus and then inseminated when detected in oestrus 3, 4 or 5 days later, the pregnancy rates in the treated cows were 10% higher than those obtained in untreated herd-mates inseminated on the same days. An increased concentration in the calving pattern should result in improved fertility because the average interval from calving to first insemination will also increase (Macmillan, 1972).

CONCLUSIONS

Future improvements in semen processing will reduce between-sire variation in CR and thereby increase average CRs. Such improvements will result from extending the post-insemination survival time of the sperm, thus reducing CR differences between cows inseminated in early oestrus and in late post-oestrus. Cow fertility may also appear to improve as a consequence of these changes in semen processing if delayed ovulation is a significant problem in the dairy cow population.

The significant differences in the average CRs between the LIAs are "artificial" differences arising from the incidence of errors in oestrus detection and the proportion of cows inseminated in early oestrus. These CR differences are important only if they are associated either with more or less concentrated calving patterns, or with the proportion of heifer calves reared as herd replacements which are AB progeny (Macmillan and Jackson, 1976).

Aids to improved oestrus detection may have the greatest impact on CRs if these aids are correctly and widely used. Improved CRs will result in an increased concentration in calving patterns and probably in reduced periods of AB usage (Macmillan *et al.*, 1973), particularly if replacement rates decline.

REFERENCES

Macmillan, K. L., 1970. *N.Z. Jl agric. Res.*, *13*: 771.
——— 1972. *Proc. Ruakura Fmrs' Conf.*: 129.
——— 1973. *Proc. N.Z. Soc. Anim. Prod.*, 33: 49.
——— 1975. *N.Z. Jl exp. Agric.*, *4*: 21.
——— 1976. *Proc. Veterinary Services Council Post-graduate Course on Reproduction in Cattle and Pigs,* Hamilton: 5.
——— 1979. *Proc. N.Z. Soc. Anim. Prod.*, 39: 168.
Macmillan, K. L.; Curnow, R. J., 1976a. *Proc. N.Z. Soc. Anim. Prod.*, *36*: 50.
——— 1976b. *N.Z. Jl exp. Agric.*, *4*: 9.
——— 1977a. *N.Z. Jl exp. Agric.*, *5*: 273.
——— 1977b. *N.Z. Jl exp. Agric.*, *5*: 279.
——— 1977c. *N.Z. Jl exp. Agric.*, *5*: 357.
Macmillan, K. L.; Fielden, E. D., 1970. *N.Z. vet. J.*, *18*: 229.
Macmillan, K. L.; Fielden, E. D.; Curnow, R. J., 1977a. *N.Z. Jl exp. Agric.*, *5*: 123.
Macmillan, K. L.; Fielden, E. D.; Morris, G. R.; Curnow, R. J., 1977b, *N.Z. Jl exp. Agric.*, *5*: 265.
Macmillan, K. L.; Hart, N. L., 1977. *Aust. J. biol. Sci.*, *30*: 297.
Macmillan, K. L.; Jackson, R. G., 1976. *N.Z. Jl exp. Agric.*, *4*: 15.
Macmillan, K. L.; Moller, K., 1977. *N.Z. vet. J.*, *25*: 220.
Macmillan, K. L.; Murray, J. B., 1974. *Dairyfmg. A.*: 121.
Macmillan, K. L.; Smith, J. F., 1978. *Proc. Ruakura Fmrs' Conf.*: FPP 127.
Macmillan, K. L.; Watson, J. D., 1971. *J. dairy Sci.*, *54*: 1526.
——— 1974. *N.Z. Jl exp. Agric.*, *1*: 309.
——— 1975a. *N.Z. Jl exp. Agric.*, 3: 1.
——— 1975b. *N.Z. Jl exp. Agric.*, 3: 11.

——— 1975c. *N.Z. Jl exp. Agric.*, *3*: 21.
——— 1975d. *N.Z. Jl exp. Agric.*, *3*: 29.
——— 1975e. *Anim. Prod.*, *21*: 243.
——— 1976. *N.Z. Jl exp. Agric.*, *4*: 21.
——— 1977. *N.Z. Jl exp. Agric.*, *5*: 11.
Macmillan, K. L.; Watson, J. D.; Shannon, A. C., 1973. *N.Z. Jl exp. Agric.*, *1*: 315.
Moller, K., 1970. *N.Z. vet. J.*, *18*: 140.
Moller, K.; Macmillan, K. L.; Shannon, P., 1972. *N.Z. Jl agric. Res.*, *15*: 252.
Salisbury, G. W.; Van Demark, N. L., 1961. *Physiology of Reproduction and Artificial Insemination of Cattle*, W. H. Freeman & Co., London: 451.
Shannon, P., 1968. *Proc. N.Z. Soc. Anim. Prod.*, *28*: 23.
——— 1978. *J. Reprod. Fert.*, *54*: 519.
Smith, J. F.; Macmillan, K. L., 1978. *N.Z. vet. J.*, *26*: 173.
Stichbury, J. W., 1968. *Proc. N.Z. Soc. Anim. Prod.*, *26*: 32.