MANIPULATING SEASONAL BREEDING PATTERNS OF RED AND FALLOW DEER

63

G.W. Asher, Ruakura Agricultural Centre, MAFTech North, Private Bag, Hamilton

M.W. Fisher and P.F. Fennessy, Invermay Agricultural Centre, MAFTech South, Private Bag, Mosgiel

SUMMARY

- Red and fallow deer calve/fawn in summer when poor feed quality often reduces lactational yields and calf fawn growth rates. Advancing the birth season by 2-8 weeks may better align the high energy demands of lactation with high quality pastures that occur earlier in spring.
- Oestrus/ovulation advancement of between 2-4 weeks in red hinds and fallow does can be achieved by 12 to 15-day progesterone CIDR treatment in conjunction with timed administration of PMSG or GnRH. However, PMSG can lead to variable ovulation rates and both treatment regimens are often association with low conception rates partly attributable to low fertility/libido of untreated sires.
- Oestrus/ovulation advancement of between 2-8 weeks in red hinds and fallow does can be achieved by strategic use of subcutaneous melatonin implants during summer. Similar treatment regimens to stags/bucks advance the seasonal attainment of fertility in line with the ovulatory response in treated females. Conception rates following treatment of both sexes are comparable to those occurring during the natural breeding sason of untreated contemparies. Melatonin treatment also alters feed intake patterns and pelage moult cycles.
- The natural timing of the breeding season of red deer can be manipulated by up to two weeks by the "stag effect"; the strategic introduction of stags following a period of hind isolation from males.
- There is some scope for genetic selection of deer that naturally calve/fawn earlier. This involves "within-breed species" selection and "cross-species" hybridization, and must be regarded as a long-term approach to advancing the birth season.

INTRODUCTION

The main species of deer farmed in New Zealand evolved in Northern Hemisphere regions in which there are well delineated climatic seasons. Rigid seasonal breeding patterns are a major evolutionary response by these species to cope with seasonal extremes in temperature and feed availability. In essence, progeny are born in the season most conducive to their survival, which in continental Europe and North America is generally summer. At this time of year temperatures are at or above ambience and there is abundant high-quality feed for lactating females. However, the New Zealand insular climate is far less extreme than the northern continental climate and feed quality and availability, particularly in the pastoral environment, are generally greater during spring (September-November) than during summer (December-February). In fact, the New Zealand summer is often a period of drought and feed deficit. While red and fallow deer have obviously acclimed well to the New Zealand pastoral environment, they have still retained the innate summer calving/fawning pattern, albeit six months out of phase with the Northern Hemisphere (Figure 1).

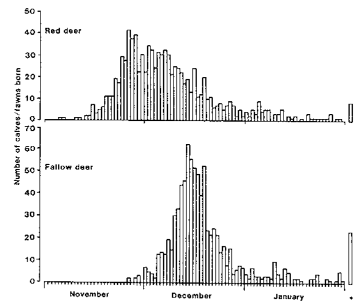

Figure 1 : Distribution of birth dates of red and fallow deer on monitored farms in the Waikato and Bay of Plenty regions, New Zealand 1980-1984.

The fundamental tennet of advancing the calving/fawning season of farmed deer in New Zealand is to better align the high energy demands of lactation with the season of greatest feed availability and quality. In theory, this should allow for better utilisation of the pasture resource and increase dam lactational yields resulting in greater calf/fawn growth rates, increased weaning weights and earlier attainment of acceptable carcass weights. Two fundamental lines of research have ben applied towards "out-of-season" breeding of red and fallow deer; (1) hormonal manipulation to advance the period of conceptions (and hence births) and (2) genetic manipulation by "within-species" and "between-species" (hybridisation) selection for an altered seasonal breeding pattern.

This paper will discuss recent achievements in "out-of-season" breeding in farmed deer, as well as address some of the problems associated with early calving/fawning patterns.

How are Seasonal Breeding Patterns Regulated?

The timing of the calving/fawning season in deer is strictly determined by the seasonality of conceptions, which occur in autumn. The primary environmental cue that synchronises conceptions in autumn is the prevailing photoperiod (ie. amount of daylight during a 24-hour period). In general, red and fallow deer exhibit sexual development in response to decreasing photoperiod and, hence, are often referred to as "short-day" breeders. The reason for relying on the photoperiod signal to mediate seasonal reproductive changes lies in the fact that for a given latitude, changes in photoperiod are constant between years and not subject to the wide annual variation that occurs for such things as temperature, rainfall, feed availability and other environmental factors that are the primary reason for adopting a seasonal pattern of breeding in the first place. In other words, photoperiod is the best predictor of a suitable time of year for conceptions to occur. To advance the calving/fawning season of deer, we must advance the mating season by either altering the animal's response to photoperiod (genetic manipulation), perception of photoperiod (melatonin treatment) or over-ride photoperiod control (GnRH or PMSG treatment).

The chain of physiological events from photoperiod perception to the instigation of reproductive activity is shown in Figure 2. The current methods of manipulating seasonal breeding patterns in deer invariably involve "splicing" into the sequence of events.

Advancing the Breeding Season of Female Deer

Female red and fallow deer normally initiate oestrous and ovulatory activity in autumn, following a period of reproductive quiesence during summer. Failure to exhibit oestrus and ovulation during summer mainly reflects inadequate pituitary stimulation of the ovaries due to the inhibitory effects of long days. The current methods of advancing the initiation of oestrous and ovulatory activity (and hence pregnancy) in female deer act by either providing additional gonadotrophin stimulation to the ovaries (to over-ride photoperiod inhibition) or by changing the animal's perception of the prevailing photoperiod.

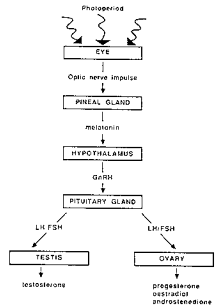

Figure 2 : Sequence of physiological events involved in the seasonal pattern of reproduction in deer. Artificial manipulation of conception dates invariably involves "splicing" into the sequence at some point.

(1) Progesterone/PMSG and GnRH treatments. Gonadotrophic stimulation, following progesterone priming with intravaginal CIDRs (CIDR type S, 9% progesterone, NZ Dairy Board, Newstead, Hamilton), has been used to advance oestrus and ovulation in red deer hinds and fallow deer does. CIDR's are inserted for periods of between 10 and 15 days. This simulates an oestrous cycle and primes the animal for an oestrous response. To further stimulate ovarian activity, GnRH (Gonadotrophin Releasing Hormone) or PMSG (Pregnant Mare Serum Gonadotrophin) are administered at or near CIDR removal.

For modest advances of oestrus and ovulation (3-5 weeks) it has become common practice to use the CIDR/PMSG regimen, whereby low doses of PMSG (200-300 i.u.) are injected at CIDR removal. However, the use of PMSG may result in variable responses, with the possibility of excessive superovulation with higher PMSG doses in both red deer (Fisher & Fennessy, 1987) and fallow deer (Asher & Smith, 1987). This can lead to a higher incidence of multiples conceived. While this may sometimes result in higher weaning percentages in red deer (Bringans & Lawrence, 1988), it has proven to be counter-productive in fallow deer due to a very high incidence of mortality of fawns born as multiples (Asher & Smith, 1987).

CIDR and PMSG treatment synchronises mating so that nearly all hinds/does are mated within several days of CIDR withdrawal. However, low fertility has been frequently reported and this may in part be due to the use of stags/bucks which are likely to be sub-fertile and of low libido prior to the onset of the normal mating season. The effectiveness of this treatment improves with increasing proximity to the normal mating season (Moore & Cowie, 1986). Further evidence of this is seen in the vastly improved pregnancy rates obtained when seasonally advanced males (ie. melatonin-treated) have been used (Fisher & Fennessy, 1987). The cost of this CIDR/PMSG treatment is in the order of $4-$8 per female.

A similar form of treatment utilises a period of pituitary stimulation with GnRH following progesterone withdrawal (Fisher, *et al.*, 1986a, b; Asher & Macmillan, 1986) and, although possibly not as effective as PMSG in inducing ovulation or as practical to administer, it may be of benefit because of a vastly reduced incidence of multiple ovulations. The method involves the post-CIDR insertion of osmotic minipump implants (Alzet Osmotic Minipump, Alza Corp., USA) containing GnRH (Figure 3).

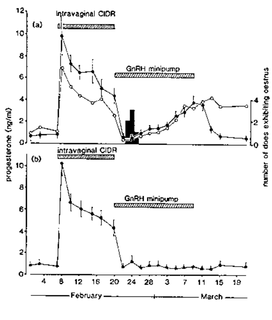

Figure 3 : Mean (±s.e.m.) serum progesterone concentrations of fallow does, recorded during the last part of the anoestrous season. All animals were treated with intravaginal CIDRs and GnRH minipumps (horizontal bars); (a) does exhibiting oestrus but not conceiving (•——•) and a doe that conceived (o——o); (b) does that failed to exhibit oestrus and a luteal response due to insufficient GnRH infusion (Asher & Macmillan, 1986).

These implants infuse constant rates of GnRH for periods of 7-14 days after CIDR withdrawal. Infusion rates of 500-1000 ng/hour GnRH have been shown to induce oestrus and ovulation up to 6-8 weeks before the natural onset of the breeding season (Fisher & Fennessy, 1987; Asher & Macmillan, 1986). However, as with CIDR and PMSG regimens, conception rates have been low, presumably due to poor stag/buck fertility and libido. The cost of this method of oestrus/ovulation control is in the order of $30-$40 per female; being somewhat expensive for practical usage.

(2) Melatonin. The pineal hormone, melatonin, has considerable potential for use in advancing oestrus and ovulation in red and fallow deer. Melatonin is secreted by the pineal gland only during darkness. As days become shorter the daily secretion increases in duration, acting to switch on reproductive activity (Figure 4). Early studies in which melatonin was administered orally in summer to red deer (Adam & Atkinson, 1984; Adam *et al.*, 1986; Webster *et al.*, 1986) and fallow deer (Asher, Day & Barrell, 1987), indicated a future role for this hormone, given a more appropriate method of administration.

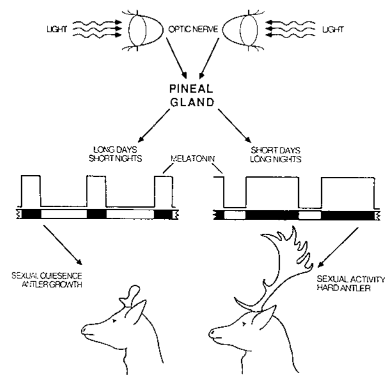

Figure 4 : Schematic representation of the effect of long and short days on melatonin secretion and seasonal reproduction development in deer.

Recent advances in implant technology include the development of small, biodegradable subcutaneous pellets which provide a constant release rate of melatonin into the animals blood stream for periods of up to 40 days (Regulin; Regulin Ltd, Melbourne, Australia). These implants each contain only 18 mg melatonin. Single implants in fallow deer and double implants in red deer elevate blood melatonin concentrations during both night and day (Figure 5).

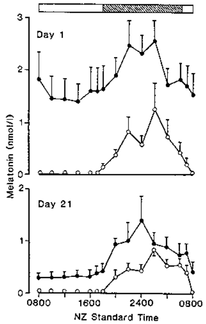

Figure 5 : 24-hour profiles of mean (±s.e.m.) plasma melatonin concentrations of melatonin-implanted (N=4; •) and control (N=4; o) fallow does; (a) 1-2 days after implantation and (b) 21-22 days after implantation. The shaded portion of the horizontal bar represents the duration of darkness (Asher, Barrell, Adam & Staples, 1988).

If given at the appropriate time of year (summer), this is effectively registered by the animal as a "short-day", serving to switch on the reproductive process.

Studies in fallow deer have shown that oestrus and conception advancement of up to 8 weeks can be achieved from a 120-day treatment regimen (ie. four single implants each given at 30-day intervals) starting in early November (Asher, *et al.*, 1988; Figure 6).

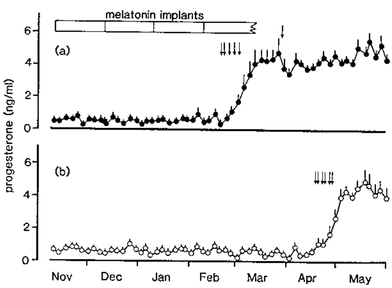

Figure 6 : Mean (±s.e.m.) plasma progesterone concentrations and individual dates of conception of (a) 6 mature fallow does given melatonin implants during summer and (b) 6 contemporary control does. Conception dates were advanced by 6-8 weeks in treated does (Asher, Barrell, Adam & Staples, 1988).

Similar treatment regimens in red deer appear to advance oestrus and conception in hinds by 4-5 weeks (Fisher, Fennessy & Milne, 1988). The difference between the two species largely reflects differences in the onset of the natural breeding season, with fallow deer being about 3-4 weeks later than red deer (Asher, 1985).

For both species, there is a limit as to how early mating and subsequent calving/fawning can be induced. Treatment starting dates occurring before October probably represent the extreme limit for an advancement response and earlier treatments may be counter-productive given that hinds/does have not been sufficiently primed by long days (termed the "photorefractory" condition) to respond to artificial "short-day" treatments. Commencement of treatment in October and early November in fallow does and yearling red deer hinds can result in mating activity in February in northern regions (Table 1; Asher *et al.*, 1988), with calving/fawning occurring in late September and October. However, the response to early November treatment in red deer appears to be somewhat later in southern regions (ie. late October-November calving; Fisher, unpubl. data). For southern regions the optimum response in yearling red deer hinds, in terms of consistency of advancement, seems to occur when treatment commences in late November/early December (Fisher, unpubl. data). As commencement of treatment is further delayed, so too is the response. Starting dates later than 30 December are probably ineffective in providing a marked degree of oestrus advancement in any region of New Zealand. In summary, the "window" for commencement of treatment lies between early November and late December.

The actual duration of treatment (ie. number of consecutive implantations at 30-day intervals) is still being researched. It would appear that treatment duration is dependant on commencement date, with duration being longest with earlier commencement date (Table 1). For example, early October start dates may require >140-day treatment period (3-4 implantations) whereas early December start dates may only require a 90-day treatment period (two implantations) although the degree of advancement will be less.

Melatonin-treated hinds and does that fail to conceive at their first advanced oestrus generally return to oestrus 18 days (red deer) or 21 days (fallow deer) later, indicating that treatment advances the entire breeding season rather than just induce a single oestrus/ovulation event, as commonly is the case with CIDR and PMSG/GnRH treatment (Figure 3). However, more importantly, conception rates to first

A few studies on fallow deer indicate that a "buck effect" is not very pronounced in the species (Asher, 1986) although it has been previously postulated that male pheromones influence the occurrence of oestrus in does (Kennaugh, *et al.*, 1979). There is evidence, however, that a "female social facilitation effect" might occur, as observed when a proportion of a doe herd were treated with CIDR's/PMSG to advance the breeding activity and the herd-mate controls were likewise advanced (Asher & Smith, 1987).

Advancing the Breeding Season of Male Deer

Male red and fallow deer are also highly seasonal with respect to reproduction. In fact, stags and bucks actually exhibit massive annual fluctuations in testicular activity such that during early summer they become effectively infertile. As autumn approaches, the testes become active, secreting large amounts of androgenic hormones (eg. testosterone) and producing spermatozoa. It is quite obvious, therefore, that significant advancement of oestrus and ovulation in females must also be accompanied by similar advancements in seasonal fertility of males if high conception rates are to be achieved.

However, the testis undertakes a rather slow transition from summer quiescence to full androgenic/spermatogenic activity in autumn. Short-term treatments with hypothalamic (GnRH) or pituitary (LH and FSH) hormones will have little overall effect on testicular development. In this respect, the most promising means of advancing testicular development and rutting activity is the use of melatonin implants (eg. Regulin).

In both species, the strategic use of melatonin implants during summer and early autumn will advance entire reproductive development in males (Figure 7), with the degree of advancement being related to the onset and duration of treatment.

The easiest approach is to treat sire stags/bucks on the same implantation regimen as for the hinds/does. In fallow deer at least, this has the effect of aligning reproductive seasonality of the two sexes (Asher, *et al.*, 1988). As with hinds/does, there are definite limitations on the degree of advancement that can be obtained with melatonin implants, and the initiation of treatment prior to early November is unlikely to further advance reproductive development in male deer.

There are three further considerations with melatonin treatments of stags/bucks. Firstly, some research evidence suggests that treatment of sire red stags alone may lead to a "social facilitation" advancement effect in untreated hinds (Fisher, unpubl. data). However, the degree of advancement of oestrus/ovulation is unlikely to be more than 2-3 weeks unless hinds are similarly treated.

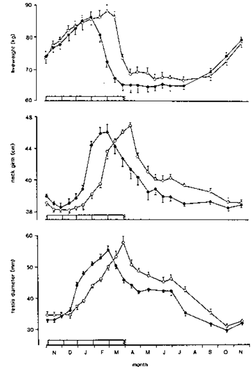

Figure 7 : Seasonal profiles of mean (±s.e.m.) liveweight, neck girth and testis diameter of 4 melatonin-treated (•) and four control (o) mature fallow bucks. Horizontal bars represent the period of implantation.

Secondly, artificial insemination programmes are often limited by the inability to obtain sufficient quality semen from sires just prior to, or during, the natural rut, when the inseminations are to be performed. Advancement of reproductive seasonality of stags/bucks with melatonin implants (and even direct photoperiod control indoors) can be used to allow for successful semen collection earlier in the season. This has particular merit if semen is to be exported to Australia, as there is a mandatory 30-day storage/quarantine period from the date of collection. Thirdly, while melatonin treatment will advance reproductive competence of male deer, in red deer at least, it appears to also have carry-over effects into the subsequent non-breeding season. Treated stags tend to become sexually quiescent earlier than untreated stags. One effect of this is earlier antler casting and subsequent initiation of velvet growth (Fisher, Fennessy & Milne, 1988). While the effects of this have yet to be fully monitored in terms of annual velvet production and yield, it may have enormous economic significance, either positive or negative.

Genetic Manipulation of the Breeding Season

The innate reproductive response to photoperiod is a genetically acquired characteristic. As with most species, there is probably a degree of genetic variation, in absolute response to photoperiod, that occurs in red and fallow deer populations. If this variation is expressed and can be quantified, then we have a powerful tool for advancing the breeding season in the long term : genetic selection.

(1) Within-species Selection. There is some evidence of natural variation in reproductive seasonality within the red deer species (*Cervus elaphus scoticus*), a proportion of which is probably due to genetic variation. Occasional "freak" stags, which tend to be out of synchrony with their herd mates, have been identified. Unfortunately, little effort has yet been made to screen the national herd for such deviants. Indeed, these stags are often considered as a nuisance by farmers, especially if they are part of a velvetting herd. Stags that cast antlers, grow velvet and rut considerably earlier than their herd mates could, in future, have an enormous genetic impact on the national red deer herd.

While a proportion of hinds may also initiate oestrous cycles considerably earlier than their herd-mates, the normal management practice of joining hinds with stags close to the time of the natural rut often means that these animals fail to become pregnant until the normal rut. Therefore, such hinds probably go unnoticed. Even given this limitation however, some farmers are actively identifying early calving hinds in an attempt to select for an altered calving season.

The natural variation in the onset of seasonal reproductive cycles in European fallow deer (*Dama dama dama*) appears to be considerably less than for red deer.

(2) Cross-breeding (hybridisaton). For red and fallow deer the term "species" refers to a wide assortment of genetically distinct populations, subspecies and even genera. Indeed, there is considerable scope for hybridising genetic lines to obtain populations with a far wider genetic base. It is noticeable that some of these potentially hybridisable "species" exhibit different breeding seasons. Therefore, should hybrids be fertile, they would exhibit altered seasonal breeding patterns.

The three main hybridization programmes with a major objective of altering the breeding season are (a) red deer x Pere David's deer (*Cervus elaphus* x *Elaphurus davidianus*), (b) red deer x rusa deer (*C. elaphus* x *C. timorensis*) and (c) European fallow deer x Mesopotamian fallow deer (*Dama dama* dama x *D. d. mesopotamica*).

While hybrids have been produced between red and Pere David's deer (Asher, *et al.*, 1988b; Figure 8) and European and Mesopotamian fallow deer, an assessment of reproductive seasonality has yet to be completed. Attempts to hybridise red and rusa deer in NZ have so far been unsuccessful but some success has been achieved in Australia, although the fertility of hybrids remains in doubt due to discrepancies in chromosome number between the parental species (2n = 68 vs 60).

Figure 8 : Two-year-old male Pere David x red deer hybrid (*Elaphurus davidianus* x *Cervus elaphus*) produced by artificial insemination. Does this represent the long-term future for manipulating the breeding season of farmed deer?

Problems Associated With Out-of-Season Breeding

While it is easy to visualise the advantages of aligning pasture production and the energy demands of reproduction, it is also necessary to understand that there are some biological limitations that will have some bearing on profitability.

(1) Some hormonal treatment regimens, particularly those that alter the animals perception of photoperiod (eg. melatonin implants), not only advance the reproductive cycle but also alter natural circannual patterns of appetite, growth and pelage replacement (moult). Care must be taken to avoid placing treated animals under stressful climatic conditions for which their physiological defenses cannot counter. For example, stags/bucks rutting in late summer may be subjected to hypothermia due to excessive activity and the presence of winter pelage during hot weather. Alternatively, treated stags/bucks are unlikely to attain peak pre-rut liveweights due to the influence of melatonin treatment on early rutting activity and appetite. These animals may have insufficient fat reserves to rut for an effective period of time.

(2) Most techniques for advancing oestrus/ovulation are associated with a lower-

induced oestrus/ovulation are generally comparable to those occurring during the normal rut providing that the males are also melatonin-treated (Asher *et al.*, 1988; Asher, unpubl. data).

$12-18 per hind and $6-9 per doe. Further studies are required to assess variables of duration, timing and magnitude of exposure to exogenous melatonin in deer.

Table 1 : Effect of melatonin-implantation treatment of yearling red deer hinds on conception rate and seasonal occurrence of oestrus and parturition at Ruakura (Asher, unpubl. data)

Number of hinds	Start of treatment	Duration of treatment	Hinds conceiving	Mean date of first oestrus (±sem)		Mean interval from start of treatment to oestrus	Mean date of calving (±sem)	
9	2 October	~180 days	8 (89%)	26 February	(±4.2)	147 days	24 October	(±5.5)
10	15 November	~150 days	9 (90%)	5 March	(±3.9)	109 days	3 November	(±5.4)
9	30 December	~120 days	8 (89%)	29 March	(±4.5)	90 days	21 November	(±3.7)
9	(controls)	-	4 (44%)	20 April	(±6.5)	-	11 December	(±8.2)

There are several factors limiting the widespread usage of melatonin in deer. Firstly, while pubertal hinds/does can be treated at any time in summer, adults must have calved/fawned by commencement of treatment. Recent studies on fallow deer (Asher, *et al.*, 1988) indicate that treatment of does in late pregnancy/parturition blocks the initiation of lactation resulting in an unacceptably high incidence of fawn mortality. However, commencement of treatment following parturition and initiation of lactation does not appear to influence subsequent lactational yields and calf/fawn growth rates (Fisher, Fennessy & Milne, 1988). Some data exists which suggests that advancement responses to melatonin treatment are less marked in lactating red deer hinds than for non-lactating animals (Barrell & Staples, 1987) although this does not appear to be the case for fallow deer (Asher, *et al.*, 1988).

In addition to clearly modifying reproductive activity, melatonin treatments alter other parameters of seasonal physiology in female deer, namely appetite, liveweight and coat growth/moulting patterns. (Webster & Barrell, 1985; Adam, *et al.*, 1986; Fisher, Fennessy & Milne, 1988). Some studies have shown reductions in liveweights of treated yearling red hinds and fallow does (Fisher & Fennessy, 1987; Asher, *et al.*, 1988) although this is not always the case in red deer (Asher unpubl. data).

Present indication are that the cost of treatment with melatonin implants will be in the order of

(3) Male-Female Interactions. In sheep the breeding season can be advanced and synchronised using the "ram effect" whereby the mere introduction of rams to anoestrous ewes, preconditioned by a period of isolation from rams, will induce the instigation of ovulatory activity earlier than normally expected (Knight, 1983). There has been considerable interest in applying these results to deer. Moore & Cowie (1986) found that untreated control red hinds run in a mating group with hinds treated with CIDR's /PMSG to advance breeding subsequently calved earlier than would have been expected of controls, suggesting a "female social facilitation effect". Other data on joining hinds with stags following a period of isolation from males are consistent with a "male social facilitation effect" or "stag effect" (Moore & Cowie, 1986). In the ram, pheromones are the likely major component of the "ram effect" (Knight & Lynch, 1980). However, in red deer, the possibility of visual and auditory ("roaring") components cannot be ignored (McComb, 1987). These effects in red deer may help in advancing the calving season by up to two weeks but have limited potential for further advancement unless combined with other treatments. However, the strategic introduction/ isolation of males to manipulate the mating season has one major advantage; it costs virtually nothing. Furthermore, it is one means that does not require the use of hormonal manipulations, although these might help in intensifying the response.

than-normal conception rate to first oestrus. Consequently, some females are likely to conceive to return oestrus, and, in the case of CIDR/PMSG or GnRH treatment, some hinds/does will revert to an anoestrous condition until the onset of the natural breeding season. As a result, rather than advance the entire calving/fawning season, these treatments often result in a very wide distribution of birth dates. The loss of birth synchrony may outweigh any advantages of early births. Those treatments that alter the animals perception of photoperiod appear more likely to maintain herd synchrony of births.

(3) Advancement of calving/fawning into spring (September/October) can be associated with a high incidence of neonate mortality due to hypothermia, particularly with fallow deer (Asher, *et al.*, 1988). Care must be taken to protect early-born fawns from unpredictable inclement weather that occurs in spring.

(4) Some evidence indicates that calves/fawns born early as a result of treatments may attain puberty in their first autumn. Precocious puberty, evidenced by exceptionally early pedicle and antler development in males and oestrus/pregnancy in females, is probably counter-productive for farmed deer as it appears to affect growth performance in the first year of life. For both species, precocious puberty seems to be most prevalent in individuals born in late September and early October. This, therefore, may place a limitation on the degree of birth advancement that is desirable.

(5) Hormonal treatments (as opposed to genetic manipulation) do not alter the overall expression of reproductive seasonality unless they are applied every year. Failure to reinstate treatments in subsequent years will result in a return to a natural breeding pattern.

A major political consideration with out-of-season breeding is the connotation associated with using "hormones" on farmed animals. Indeed, the word "hormone" raises a vitriolic response in some countries. While it is obvious that the treatment regimens described in this paper are for application in the breeding herd alone and not for use in meat-producing animals, it may be wise to consider carefully to what extent the deer industry wants to rely on these products to achieve its goal of year-round venison production. Maybe the real, long-term answer lies in genetic manipulation of the breeding season, either through "within-breed" selection or hybridisation.

REFERENCES

Adam, C.L. & Atkinson, T. (1984) Effect of feeding melatonin to red deer (*Cervus elaphus*) on the onset of the breeding season. *Journal of Reproduction and Fertility* **72** : 463-466.

Adam, C.L., Moir, C.E. & Atkinson, T. (1986) Induction of early breeding in red deer (*Cervus elaphus*) by melatonin. *Journal of Reproduction and Fertility* **76** : 569-573.

Asher, G.W. (1985) Oestrous cycle and breeding season of farmed fallow deer, *Dama dama*. *Journal of Reproduction and Fertility* **75** : 521-529.

Asher, G.W. (1986) Studies on the reproduction of farmed fallow deer (*Dama dama*). PhD thesis; Lincoln College, University of Canterbury, Christchurch, NZ.

Asher, G.W. & Macmillan, K.L. (1986) Induction of oestrus and ovulation in anoestrous fallow deer (*Dama dama*) by using progesterone and GnRH treatment. *Journal of Reproduction and Fertility* **78** : 693-697.

Asher, G.W. & Smith, J.L. (1987) Induction of oestrus and ovulation in farmed fallow deer (*Dama dama*) by using progesterone and PMSG treatment. *Journal of Reproduction and Fertility* **81** : 113-118.

Asher, G.W., Day, A.M. & Barrell, G.K. (1987) Annual cycle of liveweight and reproductive changes of farmed male fallow deer (*Dama dama*) and the effect of daily oral administration of melatonin in summer on the attainment of seasonal fertility. *Journal of Reproduction and Fertility* **79** : 353-362.

Asher, G.W., Barrell, G.K., Adam, J.L. & Staples, L.D. (1988a) Effects of subcutaneous melatonin implants on reproductive seasonality of farmed fallow deer (*Dama dama*). *Journal of Reproduction and Fertility* **84** : 679-691.

Asher, G.W., Adam, J.L., Otway, W., Bowmar, P., van Reenan, G., Mackintosh, C.G. & Dratch, P. (1988b) Hybridisation of Pere David's deer (*Elaphurus davidianus*) and red deer (*Cervus elaphus*) by artificial insemination. *Journal of Zoology, London* **215** : 197-203.

Barrell, G.K. & Staples, L.D. (1987) Melatonin implants after calving season in farmed red deer. *Proc. XV Conference of Game Biologists*, Krakow (in press).

Bringans, M.J. & Lawrence, D.W. (1988) Field experience with advanced calving and induction of twinning in deer. *Proceedings of a Deer Course for Veterinarians, Deer Branch of the NZ Veterinary Association, Course No. 5* : 36-40.

Fennessy, P.F., Fisher, M.W., Webster, J.R., Mackintosh, C.G., Suttie, J.M., Pearse, A.J. & Corson, I.D. (1986). Manipulation of reproduction in red deer. *Proceedings of a Deer Course for Veterinarians, Deer Branch of* *the NZ Veterinary Association, Course No. 3* : 103-120.

Fisher, M.W., Fennessy, P.F., Suttie, I.D., Corson, I.D., Pearse, A.J.T., Davis, G.H. & Johnstone, P.D. (1986a) Early induction of ovulation in yearling red deer hinds. *Proceedings of the NZ Society of Animal Production* **46** : 171-173.

Fisher, M.W. & Fennessy, P.F. (1987) Manipulation of reproduction in female deer. *Proceedings of a Deer Course for Veterinarians, Deer Branch of the NZ Veterinary Association, Course No. 4* : 38-44.

Fisher, M.W. & Fennessy, P.F. (1988) Advancing the calving season in red deer. *Proceedings of a Deer Course for Veterinarians, Deer Branch of the NZ Vet. Association, Course No. 5* : 17-27.

Fisher, M.W., Fennessy, P.F. & Milne, J.D. (1988) Effects of melatonin on seasonal physiology of red deer. *Proceedings of the NZ Society of Animal Production* **48** : 113-116.

Kennaugh, J.H., Chapman, D.I. & Chapman, N.G. (1977) Seasonal changes in the prepuce of adult fallow deer (*Dama dama*) and its probable function as a scent organ. *Journal of Zoology, London* **183** : 301-310.

Knight, T.W. (1983) The ram induced stimulation of ovarian and oestrous activity in anoestrous ewes : a review. *Proceedings of the NZ Society of Animal Production* **43** : 7-11.

Knight, T.W. & Lynch (1980) Source of ram pheromones that stimulate ovulation in the ewe. *Animal Reproduction Science* 3 : 133-136.

Moore, G.H. & Cowie, G.M. (1986) Advancement of breeding in non-lactating adult red deer hinds. *Proceedings of the NZ Society of Animal Production* **46** : 175-178.

McComb, K. (1987) Roaring by red deer stags advances the date of oestrus in hinds. *Nature* **330** : 648-649.

Webster, J.R. & Barrell, G.K. (1985) Advancement of reproductive activity, seasonal reduction in prolactin secretion and seasonal pelage changes in pubertal red deer hinds (*Cervus elaphus*) subjected to artificially shortened daily photoperiod or daily melatonin treatments. *Journal of Reproduction and Fertility* **73** : 255-260.

Webster, J.R., Mackintosh, C.G., Suttie, J.M., Fennessy, P.F., Davis, G.H., Staples, L.D. (1986) Advancing the breeding season of yearling red deer hinds with melatonin. *Proceedings of the Endocrine Society of Australia* **29**, Supplement 2, Abstract E5.