Proc. Assoc. Advmt. Breed. Genet. 21: 101-105

GENETIC SELECTION FOR LITTER SIZE IN CATTLE

L. R. Piper[1], B. M. Bindon[3], A. A. Swan[2], and H. G. Brewer[1]

[1]CSIRO Agriculture Flagship, F D McMaster Laboratory, Locked Bag 1, Armidale, 2350,
[2] Animal Genetics and Breeding Unit*, University of New England, Armidale, 2351,
[3]93 Bunburra Rd, Bunburra, 4310.

SUMMARY

Efficiency of production in beef cattle is limited by their relatively low reproduction rate. In this paper, we present the results of a fourteen year breeding program aimed at increasing prolificacy in a mixed beef x dairy herd, grazing at Armidale in the New England region of NSW. The herd was established by purchasing cows with a repeated history of twinning and bulls from dams with unusually high prolificacy. For the 51foundation cows with at least one subsequent calving record, the average prolificacy was 1.11 +/- 0.05 (123 total records. For all cows born in the herd, the mean ovulation rate was 1.12 and the mean prolificacy was 1.03. The twinning rate was lower than expected based on reports from other experimental herds aimed at increasing prolificacy that have been established in the USA, New Zealand and France. The observed genetic trends for ovulation rate and prolificacy were essentially zero but were moderately positive for fertility, cow rearing ability and reproduction rate. The desired outcome of generating a positive genetic trend in reproduction rate was achieved, albeit to a limited degree, but not as a result of genetic response in ovulation rate or prolificacy, the traits under direct selection pressure.

INTRODUCTION

Efficiency of production of temperate beef cattle herds is limited by their reproduction rate (calves weaned/cow joined*)*. In NSW for example, each breeding cow weans on average only 0.85 calves per year (Wilkins, personal communication). Increasing reproduction rate can increase efficiency of production (Dickerson, 1978) but the focus of genetic improvement programs has largely been directed to increasing fertility (cows calving/cow joined) by direct selection or reducing rebreeding interval or cow rearing ability (calves weaned /calf born) rather than prolificacy (calves born/cow calving). As demonstrated by multiple ovulation and embryo transfer experiments, there are no limits to increased prolificacy from the ability of the bovine ovary to produce more than one egg per cycle or from the ability of the uterus to carry more than one foetus. The cow has four functional mammary glands and is therefore equipped to suckle more than one calf. Milk production is more than adequate in many breeds and if not, could readily be improved by selection or crossing with dairy breeds. Despite these attributes, the frequency of twinning in most breeds is less than 2% but is higher within some of the large European breeds.

As noted by Piper and Bindon (1990), renewed interest in genetic manipulation of prolificacy in cattle began in the 1970's with experimental herds selected for increased twinning rate established in France, Australia, the USA and New Zealand. These new herds were based on highly selected foundation males and females (Piper and Bindon, 1979). Comparative twinning frequencies for the foundation females before and after purchase and for their first generation daughters were summarised by Morris and Day (1986). Cows with a minimum of two sets of twins prior to purchase averaged around 14 percent of twin births in subsequent calvings, while their daughters averaged about 8 percent of twin births. These

* AGBU is a joint venture of NSW Dept. of Primary Industry and the University of New England

twinning rates are in general agreement with expectations based on the repeatability and heritability of twinning and on the approximate selection intensities applied in establishing the respective herds.

In this paper we present the final results from a long term selection experiment for increased prolificacy in a mixed beef/dairy herd grazing at Armidale in the New England region of NSW.

MATERIALS AND METHODS

Foundation Animals. CSIRO began establishing its twin selection herd in 1973/74 by purchasing cows with a repeated history of twinning (2 or more sets of twins or a set of triplets or quads) and bulls from dams with unusually high prolificacy (3-10 sets of twins, 10 bulls) or because there was a history of twinning in the bulls pedigree (2 bulls). The foundation cows and bulls came from multiple herds and documented pedigree information was almost never available. The details of the twinning history of the 65 foundation cows and 12 foundation bulls were given in Piper and Bindon (1990). For the 51foundation cows with at least one subsequent calving record, the average prolificacy was 1.11 +/- 0.05 (123 total records). By contrast, 70 unselected Hereford cows, joined with the twin herd bulls and grazing throughout the year with the selected herd, had an average litter size of 1.01 (234 records). All foundation cows and bulls were culled prior to the February 1983 joining.

Cows born in the herd. As reported by Piper and Bindon (1990), all females born in the herd up to and including the 1980 drop, were retained and given from 6 to 8 opportunities to calve (more for the earlier, less for the later drops). There was no joining in 1981 (due to drought) or in 1982 (due to a change of joining time). For the 1983 to 1986 joinings, male and female replacements were chosen on the basis of selection indexes combining information on the twinning records of their dams and grand-dams (1983 and 1984) and for the later joinings, on the ovulation rate (determined by the technique of Holland *et al.*, 1981) and twinning records of their dam and the twinning records of their grand-dams. Details of the selection procedures for replacements entering the herd for the 1983 to 1989 joinings are given in Piper and Bindon (1990).

Observations and data analysis. Ovulation rate and reproduction records for females born from 1975 to 1986 have been included in the analyses for this paper. Single trait, repeated record mixed linear models, adjusting for fixed effects were fitted using Wombat (Meyer, 2007). The fixed effects fitted included calving year (1977 to 1989 with 12 levels) and cow age (in years from 2- 10 with 9 levels). The random effects included a direct additive genetic effect fitted with the numerator relationship matrix and permanent environment of the cow. There were between 418 and 453 animals in the pedigree depending on the trait, with 36 sires for all traits. Bivariate models were fitted to estimate genetic correlations but they were poorly behaved due to the small size of the data set and are not presented in this paper. Genetic trends for each trait were estimated by taking the single trait EBVs for each cow, averaging by year of birth (1975-1986) and calculating the regression between year of birth and average EBV. The annual trends shown in Figure 1 are scaled to the genetic standard deviation for each trait. The annual trends shown in Table 1 are multiplied by 100, so they are estimates of the annual average trait change per 100 cows.

RESULTS AND DISCUSSION

The number of cows, number of records, estimated means, phenotypic variances, heritabilities(+/-se) and repeatabilities (+/-se) and genetic trends for fertility (FERT), ovulation rate (OV), prolificacy (NCB), calf survival (SURV) and reproduction rate (NCW) are given in Table 1. The mean ovulation rate was 1.12 but the mean prolificacy was 1.03 which is a disappointing outcome given the selection pressure applied to prolificacy in assembling the foundation animals for the herd and to prolificacy and ovulation rate in the experimental herd for the 1983-1989 joinings. This outcome no doubt reflects the observed low heritability and repeatability of both traits and the fact that, due to the requirement build up numbers in the herd, there was no selection pressure applied in choosing incoming male and female replacements until the 1983 joining. From the 1983 joining onwards, selection intensities for male and female replacements averaged 12 percent and 72 percent respectively. The heritability and repeatability of fertility and reproduction rate were significantly higher than for ovulation rate or prolificacy but the means for both traits were below or about average for beef herds in NSW.

Genetic trends for all traits for animals born from 1975 to 1986 and calving from 1977 to 1989 are shown in Table 1 and Figure 1.

Table 1. **Number of cows, number of records, estimated means and phenotypic variances, heritability and repeatability for each of Ovulation rate, Fertility, Prolificacy, Cow rearing ability (Calf survival), Reproduction rate and Genetic trend (Annual genetic change *100)**

Trait	Cows	Records	Mean	P. Var.	Heritability	Repeatability	Trend	Sig.
FERT	380	1387	0.80	0.16	0.09(0.05)	0.27(0.03)	0.23	0.07
OV	354	1134	1.12	0.11	0.02(0.02)	0.02(0.02)	-0.02	n.s.
NCB	347	1110	1.03	0.03	0.01(0.02)	0.03(0.03)	0.02	n.s.
SURV	347	1140	0.83	0.12	0.04(0.04)	0.07(0.03)	0.10	n.s.
NCW	380	1388	0.68	0.23	0.09(0.04)	0.20(0.03)	0.47	0.01

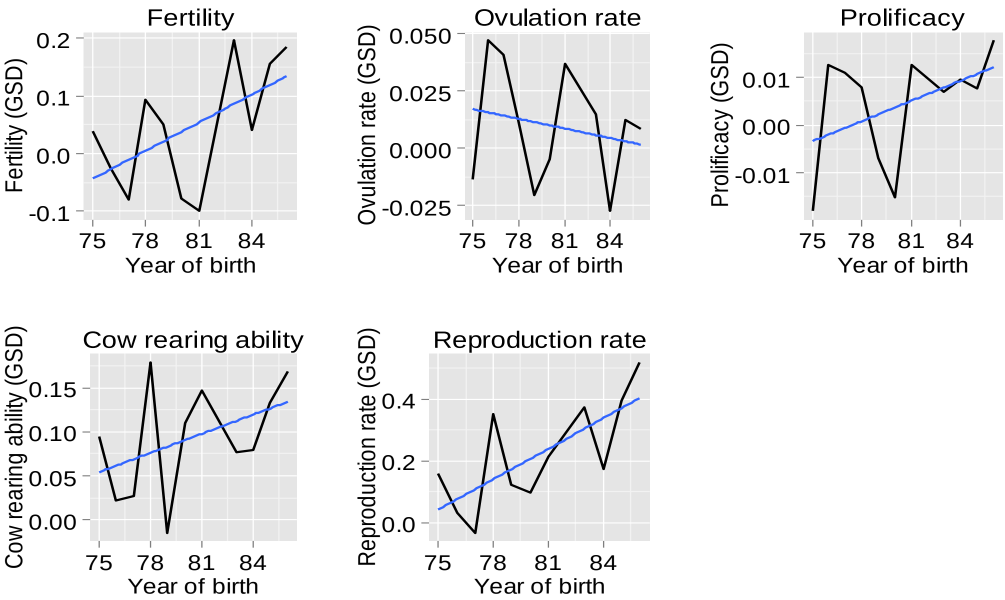

Figure 1. Genetic trends in fertility, ovulation rate, prolificacy, cow rearing ability and reproduction rate, scaled by the genetic standard deviation (GSD) for each trait.

The genetic trends for ovulation rate and prolificacy were essentially zero which is disappointing given the positive but modest selection pressure applied to both traits in choosing replacement males and females for the 1983 to 1989 joinings. By contrast the genetic trends for fertility, calf survival and reproduction rate were positive indicating slow genetic improvement in all three traits but especially in fertility and reproduction rate.

As indicated earlier, it is disappointing that the traits under direct selection pressure, ovulation rate and prolificacy, showed little or no response over the life of the experiment. Because of that observed outcome, it is not clear why there was a positive genetic trend in fertility, cow rearing ability and reproduction rate. One possible explanation may be that selection for prolificacy puts direct pressure on fertility because prolificacy cannot be observed unless the cow is pregnant. This positive genetic trend in fertility, accompanied by a positive but not significant trend in cow rearing ability has resulted in a positive but modest genetic trend in reproduction rate. The desired direction of outcome was achieved, albeit to a limited degree, but not as a result of genetic response in ovulation rate or prolificacy, the traits under direct selection pressure.

The results from this experimental herd are in sharp contrast to the results obtained in experimental herds undergoing long-term selection for increased prolificacy in New Zealand (Morris and Wheeler, 2002 and Morris, personal communication, 37 percent of twin births in 2006-2008) and in the Clay Center herd in the USA (Echternkamp *et al.*, 2002, 52% of twin births in 2000). In both these herds, as in the herd reported in this paper, the foundation animals were highly selected for repeated history of twinning. By contrast with the selection procedures employed in the present study, replacements in the Clay Centre herd in the USA, were chosen on the basis of repeated (6-8) observations of ovulation rate determined by rectal palpation (incoming young female replacements) and on the basis of repeated ovulation rate progeny tests, and in later years QTL marker adjusted EBV, for incoming replacement males.

The difference in response in prolificacy between the Clay Centre herd and our experimental herd may be due to a combination of factors including large differences in selection accuracy and intensity, the number of years that effective selection was able to be applied and in the difference in the initial response achieved in the offspring of the highly selected foundation males and females. It is also probable that there were differences in the accuracy of the records of the foundation cows and bulls. By contrast with the USDA herd, in the CSIRO herd these records were generally not documented in herd recording schemes and were based on the testimony of the producers who supplied the foundation cows and bulls. The overall response in prolificacy in the CSIRO herd may have increased had the experimental breeding program been allowed to continue. However, a decision to redirect resources to pursue non-genetic methods of increasing prolificacy in cattle resulted in the breeding program being terminated when the 1986 drop animals had their second calving in 1989.

ACKNOWLEDGEMENTS

The skilled and dedicated contributions to the conduct of this experiment during its fourteen year lifetime of Yvonne Benton, Michelle Cheers, Richard Farrell, Edward (Bud) Holland, Robert Nethery, Grant Uphill and Ross McCrae are gratefully acknowledged.

REFERENCES

Dickerson, G.E. (1978) *Anim. Prod*. **27**:367.

Echternkamp, S.E., Thallman, R.M., Kappes, S.M. and Gregory, K.E. (2002) *Proc. 7th Wld. Congr. Genet. Appld. Livest Prod., Session 08 Reproduction, Communication No 08-12*.

Holland, E.J., Bindon, B.M., Piper, L.R. Thimonier, J, Cornish, K.A. *et al.* (1981) *Reproduction Science* **4**:127.

Meyer, K. (2007) *Journal of Zhejiang University. Science. B* 8 (11): 815–21. doi:10.1631/jzus.2007.B0815.

Morris, C.A. and Day, A.M. (1986) *Proc 3rd Wld. Congr. Genet. Appld. Livest. Prod.* **XI**: 14.

Morris, C.A. and Wheeler, M. (2002) *N.Z. J. Agric Res.* **45**: 17.

Piper, L.R. and Bindon, B.M. (1979) *Proc. NZ Soc. Anim. Prod* **39**: 224.

Piper, L.R. and Bindon, B.M. (1990) *Proc. Assoc. Advmt. Anim. Breed. Genet.***8**: 381.