The influence of age-group structure on genetic gain and productivity in registered herds of three beef breeds

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Demographic data were collected on one privately owned stud herd each of the Bonsmara, Brahman and Drakensberger beef breeds, farmed extensively in different natural environments in the Republic of South Africa, to study the influence of herd age-group structure on the rate of genetic gain and production. The number of calves weaned per 100 cows mated varied from 51 to 69 between different herds and cow age-group structures. All three herds required at least four cow age-groups to maintain population size and should attain maximum annual genetic gain with six cow and three bull age-groups. This age-group structure secured almost maximum production in terms of calves weaned and weaning mass per cow mated. It is concluded that an age-group structure with six cow and two to four bull groups should allow near maximum genetic gain in most South African beef cattle studs with weaning rates between 60 and 70 calves per 100 cows mated. Herds with a weaning rate of 71 to 80% should contain five cow and two or three bull age-groups for maximum genetic gain.
S. Afr. J. Anim. Sci. 1984, 14: 110 – 114

Demografiese data is ten opsigte van drie privaat vleisbeesstoetkuddes, een elk van die Bonsmara-, Brahman- en Drakensbergerrasse, versamel met die doel om die invloed van kuddeouderdomstruktuur op genetiese vordering en produksie te bestudeer. Hierdie kuddes word ekstensief in verskillende natuurlike omgewings van die Republiek van Suid-Afrika aangehou. Die aantal kalwers gespeen per 100 koeie gepaar, het van 51 tot 69 gevarieer tussen verskillende kuddes en koeiouderdomstrukture. Al drie die kuddes moet minstens vier koei-ouderdomsgroepe bevat om 'n vaste kuddegrootte te handhaaf, terwyl maksimum jaarlikse genetiese vordering met ses koei- en drie bulouderdomsgroepe behaal kan word. Hierdie ouderdomstruktuur het ook bykans maksimum produksie in terme van aantal kalwers gespeen en speenmassa per koei gepaar, verseker. Daar is tot die gevolgtrekking gekom dat 'n ouderdomstruktuur met ses koei- en twee tot vier bulouderdomsgroepe in die meeste Suid-Afrikaanse vleisbeesstoete met speenpersentasies van 60 tot 70, bykans maksimum genetiese vordering en produksie teweeg sal bring. Kuddes met 'n speenpersentasie van 71 tot 80 moet uit vyf koei- en twee of drie bulouderdomsgroepe bestaan vir maksimum genetiese vordering.
S.-Afr. Tydskr. Veek. 1984, 14: 110 – 114

Keywords: Age-group structure, genetic gain, productivity, beef cattle

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Received 2 November 1983

Introduction

Considerable progress has been made with the scientific breeding of beef cattle in South Africa since the Beef Cattle Performance and Progeny Testing Scheme was instituted in 1960. Not only has membership increased from 30 in 1960 to 1 822 in 1982, but the number of calves and young animals subjected to objective measurement has been increased from 2 160 to 210 898 during the same period (Hofmeyr, 1978 and Bosman, 1982).

Selection procedures and mating systems are recognized as the basic components of a breeding plan and in practice aspects such as age at selection, mating season, percentage of male animals in the breeding herd, inbreeding, etc. are also considered. On the other hand, the influence of the number of female and male age-groups on genetic gain, production and reproduction is often ignored. It is true, however, that sufficient data for the study of this aspect only become available after several years of objective measurement, especially when populations are small as in South African stud herds of beef cattle.

In sheep where large populations are more readily available, Turner (1963) and Turner, Brown & Ford (1968) demonstrated that the age structure has a significant influence on genetic gain in Merino flocks. This is due to the inverse relationship between the intensity of selection and the generation interval which becomes apparent when the number of male and female age-groups is changed. An important conclusion from their results was that the influence of the number of female age-groups on genetic gain was greatly diminished with decreasing reproduction rates. This is, of course, of importance in beef cattle where reproduction rates compare with the lowest values given for sheep by Turner *et al.* (1968). Nevertheless, no information is available on the ideal age-group structure for maximum genetic gain in South African beef herds. Furthermore, the degree of compatibility of the ideal age-group structure for maximum genetic gain and that for maximum production of surplus animals has presently not been studied. It is the purpose of this paper to report some information in this regard.

Material and Procedures

The data for this investigation were obtained from the records of three established, privately owned stud herds, one each of the Bonsmara, Brahman and Drakensberger breeds kept under extensive natural grazing conditions in the Northern Cape and Eastern Transvaal Highveld. The Bonsmara herd, which was the largest, contained 765 breeding cows in 1979, while there were 180 cows in the Brahman herd in 1982 and 224 in the Drakensberger herd. For the Bonsmara herd data were collected for a five year period and for an eight year period each, for the other two breeds.

Presently cows are retained in the three breeding herds for as long as they are judged profitable by the respective breeders. Cows were bred for up to 11 years in the Bonsmara herd, to 13 years in the Brahman herd and to 12 years in the Drakensberger herd (Table 1). Actual ages at birth of the first and last calves being two and 12, two and 14 and three and 14 years respectively. Even older cows than the terminal ages mentioned were found in all three herds but their numbers were so small that they were excluded from the investigation.

Data collected included number of cows mated, calved, died and sold within each cow age-group every year. The number of stillborn calves, calves lost before weaning and from weaning to mating age were also recorded on a cow age-group basis. For each breed, observations within years and within cow age-groups were expressed as percentages of the number of cows mated and averaged over all the years of observation. Curvilinear regressions were fitted for clearer descriptions of the relationships between the different observations and age of cow. The influence of age-group structure on genetic gain, production and reproduction in the three herds was studied by procedures developed by Andrewatha & Birch (1954) as described by Turner & Young (1969).

Table 1 Number of calves born and weaned per cow mated when the number of cow age-groups is increased from 1 to 13

Number of cow age-groups	Bonsmara		Brahman		Drakensberger	
	Born	Weaned	Born	Weaned	Born	Weaned
1	0,61	0,51	0,69	0,57	0,67	0,61
2	0,64	0,55	0,72	0,59	0,69	0,63
3	0,65	0,58	0,74	0,61	0,70	0,65
4	0,67	0,60	0,76	0,63	0,72	0,67
5	0,68	0,62	0,78	0,64	0,73	0,68
6	0,69	0,63	0,77	0,65	0,73	0,69
7	0,69	0,64	0,77	0,65	0,73	0,69
8	0,70	0,64	0,77	0,65	0,73	0,69
9	0,70	0,64	0,76	0,64	0,73	0,69
10	0,69	0,64	0,74	0,63	0,72	0,68
11	0,69	0,63	0,73	0,62	0,71	0,67
12			0,71	0,61	0,70	0,66
13			0,70	0,59		

Results and Discussion

Since the three beef cattle populations included in this study were situated in different environments and were subjected to different management regimes, any observed differences or similarities between them cannot be interpreted as being mainly genetic or mainly environmental in origin. Determining such differences or similarities, was, of course, not the object of this study but to establish to what extent they differ with regard to their ideal age-group structures.

The change in the reproduction rate of cows with increasing age in the three herds studied, is presented in Figure 1a to c. All three show the same basic tendency of rising fertility with increasing age up to seven years of age after which reproduction rate starts a decline. The Brahman herd (Figure 1b) showed the sharpest decline after seven years. In this herd,

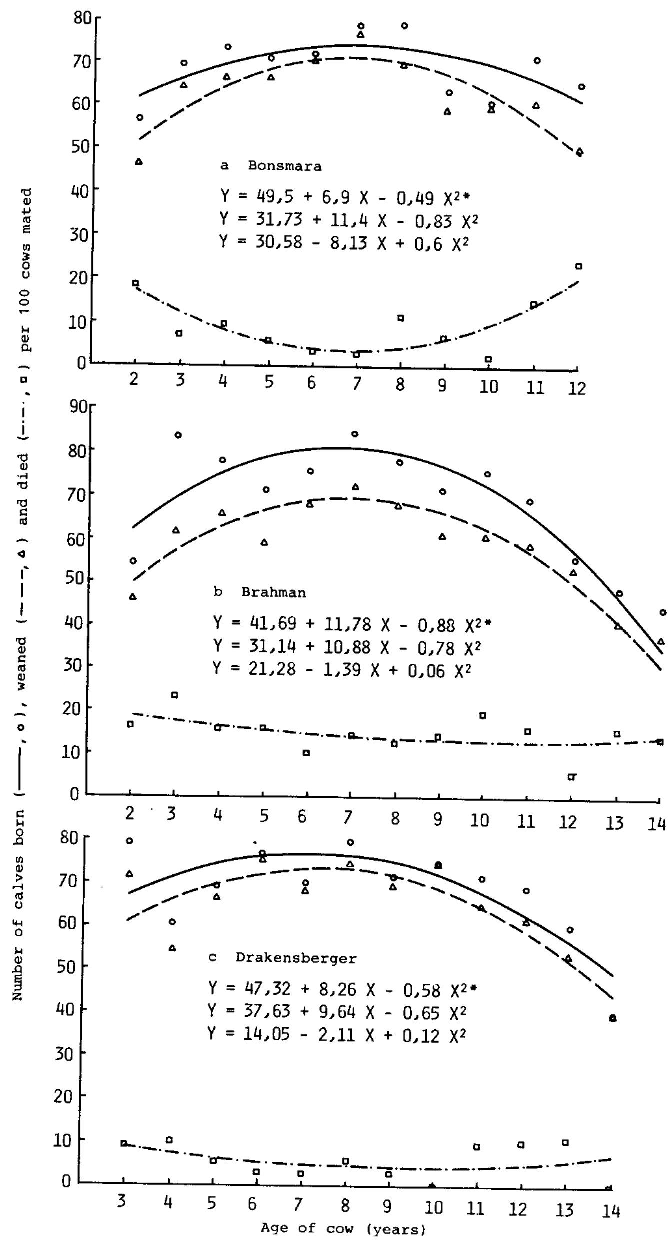

Figure 1 Change in reproduction rate and calf death rate with age of cow in the three beef stud herds

*Regression equations given in same sequence as the regression lines

this phenomenon may be related to the retention of a large proportion of imported cows on which the herd was founded, to rather senile age. These cows were probably not as well adapted as those born locally, especially those of later generations. Also the weaning mass of calves produced in their prime were not as good as those of their descendents in the same herd. Calf death-rates showed a similar pattern in the Brahman and Drakensberger herds, but were considerably higher in the Brahman herd (Figure 1b and c). In the Bonsmara herd (Figure 1a) the lower viability of the calves of young and old cows is more striking.

Using the information in Figure 1 to determine the reproduction rate of herds containing different numbers of cow age-groups (presented in Table 1) shows that the Bonsmara herd should reach its highest birth rate when cows are bred for eight years (0,7 calves per cow mated). In the other two herds this point would be reached with five cow age-groups. More important, however, is the fact that the Bonsmara herd will obtain its highest weaning rate of 0,64 calves per cow mated with seven cow age-groups and the other two herds with six. On the other hand, the weaning rate of the Bonsmara herd will only be reduced by 1,5% (0,64 to 0,63 calves per cow mated) when the number of cow age-groups is reduced to six. It should be mentioned, however, that the Bonsmara herd was in an expansion phase during the period of this study and consequently contained an above-average proportion of young cows. Therefore it may be reasoned that with a normal replacement rate, the reproduction and production rate of this herd should be somewhat higher and probably more comparable to that of the other two herds.

The pattern of erosion of the breeding cow herd with increasing age of cow, was very similar in all three herds (Figure 2a to c). These losses include deaths as well as culls because of failing production. The influences of these patterns on the replacement requirements of the three herds when different numbers of cow age-groups are maintained, are presented in Table 2. Once more the similarity between the herds in this regard, is obvious. Also shown in Table 2 is the number of heifers of breeding age available in herds with differing cow age-group numbers. Although the Drakensberger herd seems

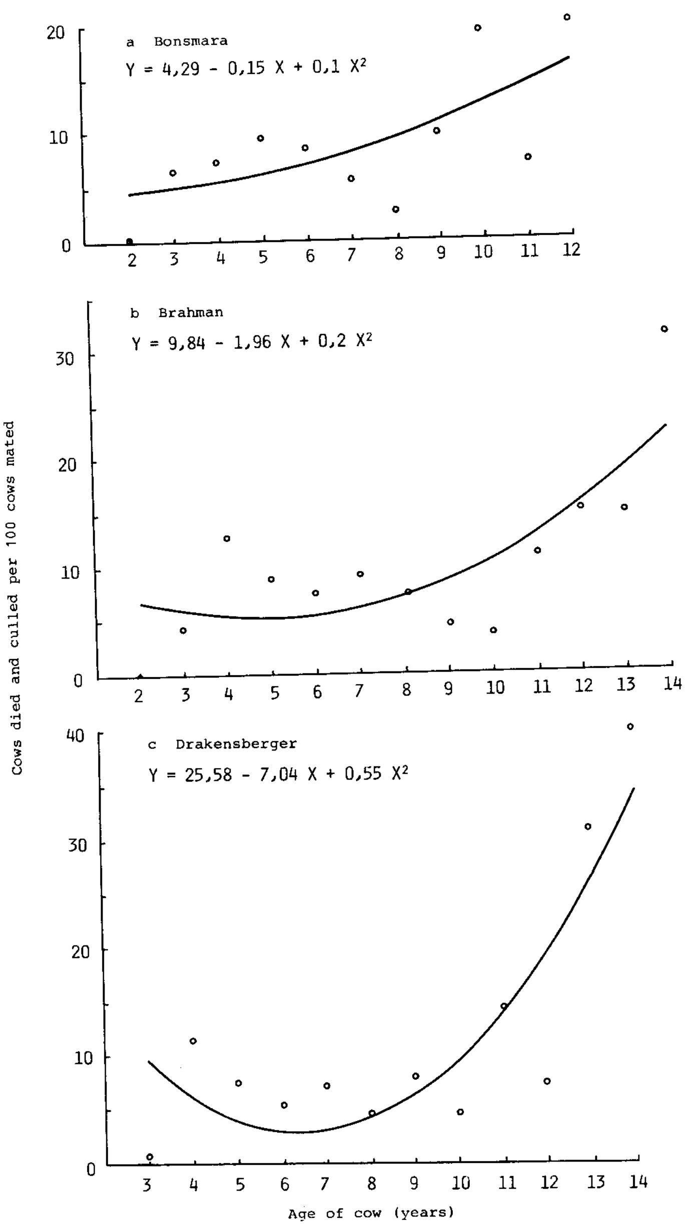

Figure 2 Change in cow death rate (died and culled) with age of cow

the most prolific and the Bonsmara the least, the differences are small. More important is the observation that all three herds require at least four cow age-groups to maintain a fixed herd size. The number of replacements required and breeding heifers available for the three herds being 0,27 *versus* 0,29; 0,27 *versus* 0,31 and 0,28 *versus* 0,32 animals per cow mated, for the Bonsmara, Brahman and Drakensberger herds, respectively.

Table 3 gives the expected number of heifers reaching joining age produced per cow during her life time in the breeding herd for herds with different numbers of cow age-groups. Also given is the potential growth rate in population size if all heifers reaching joining age are absorbed into the breeding herd. Once more it is obvious that none of the three herds can maintain their population size with less than four cow age-groups. The potential number of breeding heifers produced per cow mated being 1,09; 1,13 and 1,15 for the Bonsmara, Brahman and Drakensberger herd, respectively. At present the Bonsmara herd shows the greatest potential for herd expansion (16% per year with 11 cow age-groups). Although somewhat lower, the Brahman (13%) and the Drakensberger (14%) will reach their highest growth potentials when nine age-groups of cows are maintained. The advantage of the Bonsmara herd in spite of its slightly lower reproduction is probably related to the lower erosion of its breeding cow herd. On the other hand, since this herd was in an expansion phase during the period of this study it can be assumed that the culling of older breeding cows may not have been as strict as in the other two herds.

The expected genetic gain with different age-group structures for breeding cows and bulls in the three herds is illustrated in Figure 3a to c. In these graphs the genetic gain is expressed in the general form of mean selection intensity divided by mean generation length $(\bar{i}/\bar{L})$ (Turner & Young, 1969). To obtain the predicted annual selection response for any particular trait for a given age-group structure, the appropriate $\bar{i}/\bar{L}$ value read from Figure 3, is multiplied by the heritability and phenotypic standard deviation of the trait in question. Figure 3 shows that all three herds will have the greatest genetic gain when six cow age-groups are maintained. In all three herds the use of bulls for only one year will markedly reduce the rate of genetic gain. On the other hand, keeping bulls for two, three or four breeding years will have little influence on the rate of genetic gain, especially in the Brahman and Drakensberger herds. Genetic gain is, of course, not the only factor determining the number of years a bull is used. Even with home-bred bulls economic factors and potential inbreeding must be considered.

The finding that all three herds require the same age-group structure for maximum genetic gain in spite of smaller differences in prolificacy and in their reproduction and erosion patterns, is of practical importance. This seems to indicate that other beef cattle herds or breeds with roughly similar demographic statistics will most probably have the same ideal age structure for maximum genetic gain. However, it must be warned that this age-group structure is not generally applicable. For instance, processing data on an American Hereford herd published by Rice, Woodward, Quesenberry and Willson (1961) in the same way, showed an ideal age-group structure of five cow and two bull groups. The reproduction rate in their herd was, however, considerably higher than those of the present study, for example 0,77 calves weaned per cow mated in a six cow age-group herd, compared to 0,69 calves for a similar age-group structure in the Drakensberger which was the most prolific in the present study. Furthermore, the American Hereford herd could maintain its population size with only three cow age-groups, compared to four in all three herds of

Table 2 Number of heifers reaching joining age and required as replacements per cow mated when the number of cow age-groups is increased from 1 to 13

	Bonsmara		Brahman		Drakensberger	
Number of cow age-groups	Heifers available	Replacements required	Heifers available	Replacements required	Heifers available	Replacements required
1	0,25	1,00	0,28	1,00	0,29	1,00
2	0,27	0,51	0,29	0,51	0,31	0,52
3	0,28	0,35	0,30	0,35	0,32	0,36
4	0,29	0,27	0,31	0,27	0,32	0,28
5	0,30	0,22	0,31	0,22	0,33	0,23
6	0,31	0,19	0,31	0,19	0,33	0,19
7	0,31	0,17	0,31	0,17	0,33	0,17
8	0,31	0,15	0,31	0,15	0,33	0,15
9	0,31	0,14	0,31	0,14	0,33	0,14
10	0,31	0,13	0,31	0,13	0,33	0,13
11	0,30	0,12	0,30	0,12	0,33	0,12
12			0,29	0,12	0,32	0,12
13			0,29	0,12		

Table 3 Number of heifers reaching joining age per cow during her life time and the potential population growth rate[a] when the number of cow age-groups are increased from 1 to 13

	Bonsmara		Brahman		Drakensberger	
Number of cow age-groups	Heifers/ cow	Growth rate	Heifers/ cow	Growth rate	Heifers/ cow	Growth rate
1	0,25	0,50	0,28	0,65	0,29	0,66
2	0,52	0,77	0,56	0,85	0,58	0,86
3	0,80	0,93	0,85	0,96	0,87	0,97
4	1,09	1,02	1,13	1,03	1,15	1,03
5	1,36	1,08	1,40	1,07	1,44	1,08
6	1,62	1,11	1,64	1,10	1,71	1,10
7	1,86	1,13	1,87	1,11	1,96	1,12
8	2,06	1,14	2,06	1,12	2,19	1,13
9	2,24	1,15	2,22	1,13	2,38	1,14
10	2,37	1,15	2,34	1,13	2,53	1,14
11	2,47	1,16	2,42	1,13	2,64	1,14
12			2,47	1,13	2,71	1,14
13			2,49	1,13		

[a] Represents the increase in population size when all heifers reaching joining age enter the breeding herd and the number of age groups given in column one is maintained

the present study.

The results obtained in the present study as well as those with the data of Rice *et al.* (1961), are in close agreement with results obtained for Merino sheep with similar reproduction rates by Turner *et al.* (1968). An important finding by Turner *et al.* (1968) was that the ideal number of ewe age-groups was not only reduced with an increasing reproduction rate, but that the change in genetic gain with a change in the number of age-groups was more pronounced. This means that the higher the reproduction rate of the population, the more important it is to maintain the ideal age-group structure if maximum genetic gain is aimed at.

In stud beef herds not all surplus animals can be sold as breeding material and a large proportion of the income is derived from the beef market. Therefore, the compatability of the ideal age structure for maximum genetic gain with that for the maximum weaning percentage or for the highest weaning mass

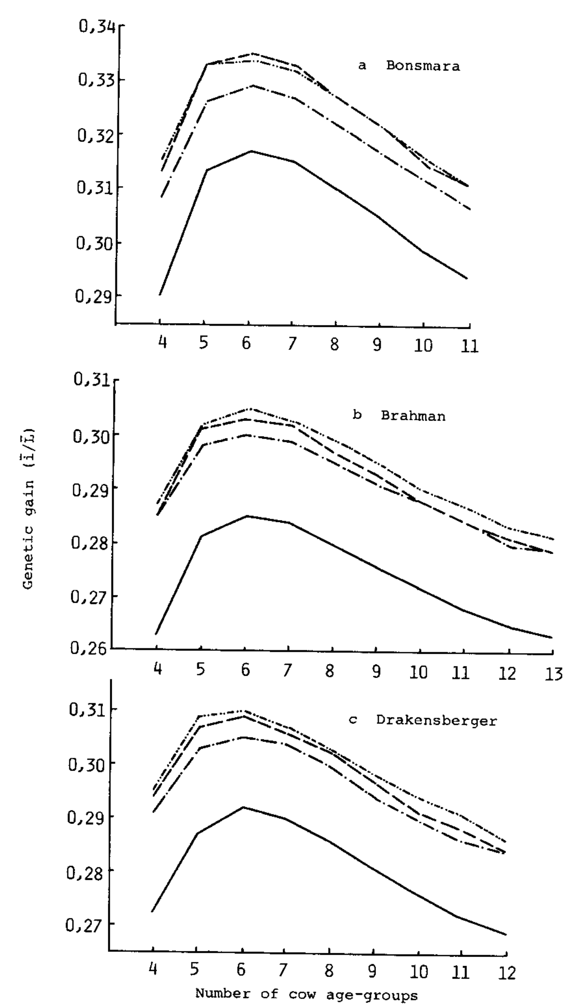

Figure 3 The influence of the number of cow and bull age-groups on the expected genetic gain in the three beef stud herds
———— 1 Bull age-group
- - - - - - - - 2 Bull age-groups
—··—··— 3 Bull age-groups
—·—·— 4 Bull age-groups

per cow mated is of importance. As shown earlier (Table 1) the Brahman herd (0,65) and the Drakensberger herd (0,69) were expected to produce the maximum number of calves per cow mated with six cow age-groups. Such an age structure is, of course, exactly the same as that for maximum genetic gain. The Bonsmara herd attained its maximum weaner production (0,64) with seven cow age-groups which will only be reduced by 1,5% when only six age groups are kept. On the other hand, with seven cow age-groups in the Bonsmara herd, the expected genetic gain will still be 99,4% of maximum.

From Table 4 it can be seen that the Bonsmara herd would probably achieve the highest weaning mass per cow mated with eight (124,3 kg) or nine (124,4 kg) cow age-groups. With six cow age-groups (121,5 kg), weaning mass will still be 97,7% of maximum. The sacrifice in genetic gain when eight cow age-groups are used will be 2,4%. In the Brahman herd the best weaning mass per cow mated (127,3 kg) is expected with seven cow age-groups while the value (126,9 kg) for six cow age-groups is virtually the same. Similar to the Bonsmara herd the Drakensberger herd will also attain its highest weaning mass per cow mated with eight (143,2 kg) or nine (143,5 kg) cow age-groups. With six cow age-groups as for maximum genetic gain, this herd should produce a mean weaning mass per cow mated (139,6 kg) which is 97,3% of maximum. The reduction in genetic gain when eight cow age-groups are used to attain maximum weaning mass, will be approximately 2,3% as in the Bonsmara herd.

Table 4 Weaning mass produced per cow mated when the number of cow age-groups is increased from 1 to 12

Number of cow age-groups	Weaning mass/cow mated (kg)		
	Bonsmara	Brahman	Drakensberger
1	95,8	108,8	114,3
2	103,2	114,7	121,0
3	109,4	119,4	126,9
4	114,6	123,0	132,1
5	118,6	125,5	136,3
6	121,5	126,9	139,6
7	123,4	127,3	141,9
8	124,3	126,8	143,2
9	124,4	125,4	143,5
10	123,6	123,4	143,0
11	122,2	121,0	141,9
12			140,5

Conclusion

Beef cattle stud herds farmed extensively under South African conditions and weaning between 60 and 70 calves per 100 cows mated, will probably attain their maximum genetic gain with six cow and two to four bull age-groups in the breeding herd. Strictly speaking, this only holds true when both cow and bull replacements are bred within the herd. In daughter studs where bull replacements are obtained from parental studs these results will only be applicable when replacement bulls are continually bought from the same stud which itself is making the maximum possible genetic progress. Although South African data were not available, results obtained with an American Hereford herd and with Australian Merino sheep lead to the conclusion that herds weaning between 71 and 80 calves per 100 cows mated will probably achieve their maximum genetic gain with five cow age-groups and two or three bull age-groups.

Under normal circumstances and within the limits studied, the ideal age-group structure for maximum genetic gain also gives near maximum production in terms of number of calves weaned and weaning mass produced per cow mated. Smaller adjustments in the cow age-group structure to suit practical considerations should not have a serious influence on the expected genetic gain, especially in less prolific herds. As in the present herds studied, most South African beef cattle studs retain breeding cows for too long to secure maximum genetic gain. Economic factors relating to the relatively long unprofitable period before heifers calve for the first time most certainly plays an important role in this respect.

Acknowledgement

The participating stud breeders are thanked for their kind co-operation and interest during the execution of this study.

References

BOSMAN, D.J., 1982. Scheme matters. National beef cattle performance and progeny testing scheme newsletter 34, 3. ADSRI, Irene, South Africa.

HOFMEYR, J.H., 1978. Die nasionale vleisbeesprestasie- en nageslagtoetsskema. National beef cattle performance and progeny testing scheme newsletter 21, 5. ADSRI, Irene, South Africa.

RICE, F.J., WOODWARD, R.R., QUESENBERRY, J.R. & WILLSON, F.S., 1961. Fertility of beef cattle raised under range conditions. Agric. Res. Service, U.S. Dept. Agric., Montana Agric. Station, Bozeman. Bulletin 561.

TURNER, HELEN, N., 1963. Does it pay to keep older sheep? *Proc. Symp.* Prime lamb production, 52. *N.S.W. Branch Aust. Soc. Anim. Prod.*

TURNER, HELEN, N., BROWN, G.H. & FORD, G.H., 1968. The influence of age structure on total productivity in breeding flocks of Merino sheep. I. Flocks with a fixed number of breeding ewes, producing their own replacements. *Aust. J. Agric. Res.* 19, 443.

TURNER, HELEN, N. & YOUNG, S.S.Y., 1969. Quantitative genetics in sheep breeding. Melbourne: Macmillan.