AN INVESTIGATION OF STRATEGIES TO IMPROVE THE WEANING WEIGHT OF MASHONA CATTLE ON RANGE IN ZIMBABWE USING A MATERNAL EFFECTS MODEL.

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SUMMARY

This paper reports changes in the weaning weights of progeny in a simulated population of Mashona cattle with a h_A^2, h_M^2 and r_{AM} of 0.24, 0.39 and -0.28, respectively. A nucleus herd was developed using high merit bulls from commercial ranches and randomly selected bulls from the small holder farms emulating beef production systems used in Zimbabwe. The following 5 strategies were used to select breeding animals namely; using mass selection (MASS); selecting breeding animals on their direct genetic values (DIRECT); selecting breeding animals on their maternal genetic values (MATERNAL); selecting bulls on their direct genetic values and cows on their maternal genetic values (COMBINED); and selecting breeding animals first on their maternal then on their direct genetic values (MATERNAL/DIRECT). The progeny born in the first year of selection using COMBINED, MASS, DIRECT, MATERNAL/DIRECT and MATERNAL had standardised weaning weights (± s.e) of 47.1 ± 0.4, 32.8 ± 0.4, 31.0 ± 0.4, 29.4 ± 0.4 and 29.3 ± 0.4 kg, respectively. In the final year the latter strategies resulted in standardised weaning weights of 41.8 ± 0.46, 40.3 ± 0.46, 42.1 ± 0.46, 44.8 ± 0.46 and 45.5 ± 0.46 kg, respectively. Strategies selecting breeding animals on their maternal genetic values resulted in the highest responses of weaning weight in both the nucleus and testing herds. The COMBINED strategy produced progeny with the heaviest weaning weights in the initial years of the selection programme. It was emphasized that in practise the effectiveness of the strategies of choice will depend on the accuracy with which maternal genetic values are estimated.

INTRODUCTION

The establishment of nucleus herds of indigenous breeds in Zimbabwe is complicated by the existence of two major pools of indigenous cattle, namely the herds in small holder farming areas and those in large commercial ranches. The major challenge to the creation of nucleus herds of indigenous cattle is the establishment of breeding structures that can exploit the genetic improvement already accomplished in commercial herds and also incorporate genes, of high merit, from small holder farms. The objectives of this study was to evaluate the genetic responses that could be attained in a simulated nucleus herd established through the incorporation of genes from these two sources.

MATERIALS AND METHODS

Three populations representing animals in commercial ranches, a testing station (research station) and small holder farms were simulated using a model that included both direct and maternal genetic effects and the parameters shown in Table 1. The management of animals in the commercial herds and the testing herds were similar. All calves were weaned when they were between 6 to 9 months old. Male weaners were performance tested and the top ranking 25 percent were selected for progeny testing. All animals were bred when they were 2.5 to 3 years old.

Twenty years of selection were simulated during which a nucleus herd comprising 100 breeding cows, when fully established, was developed in the first 10 years. Breeding animals were of mixed age and truncation selection was practised. The commercial herd at any given time comprised of 3000 breeding animals including 120 bulls and the small holder genetic pool contained 10000 breeding bulls. The station herd of 500 breeding cows was separated into a nucleus and a testing herd at the initiation of the programme. The testing herd was used to progeny test young bulls and also to produce replacement bulls for the nucleus. In the first year 50 cows with the highest breeding values were moved from the testing herd into the nucleus. Five high merit bulls from the commercial herd were also transferred into the nucleus. Replacement bulls bred from within the nucleus herd were used without testing. Breeding cows were culled after weaning two calves. During each year 10 bull calves were randomly selected from the small holder farms and joined with 45 bull calves born in the testing herd. These bulls were subsequently performance tested and the top 25% high rank bulls were kept for progeny testing. Bulls were only used once in the test herd and breeding cows were culled after weaning two calves. Four high rank bulls from the progeny tested group were transferred into the nucleus herd. The nucleus herd was structured to hold 100 breeding cows and the test herd held 500 breeding cows.

Four commercial bulls were transferred to the nucleus herd each year during the development of the nucleus herd and after the tenth year only two bulls were transferred. Every year ten cull cows from the nucleus herd were transferred to the testing herd in an attempt to improve its genetic merit.

The following 5 strategies were used to select animals of high genetic merit; using mass selection (MASS); selecting breeding animals on their direct genetic values (DIRECT); selecting breeding animals on their maternal genetic values (MATERNAL); selecting bulls on their direct genetic values and cows on their maternal genetic values (COMBINED); selecting breeding animals first on their maternal genetic values and then on their direct genetic values (MATERNAL/DIRECT). Each strategy was replicated 100 times.

RESULTS

The COMBINED strategy of selecting animals resulted in the heaviest progeny weaning weights in the nucleus during the first year of the selection program (Table 2). The MASS nucleus had the second heaviest weaning weights in the first year. The weaning weights of the first progeny of animals born in the nucleus herds selected using MATERNAL/DIRECT and MATERNAL strategies were similar. The latter two strategies selected the heaviest animals into the nucleus herd after the programme was run for 20 years and they also produced the highest responses. The MASS nucleus produced the lightest progeny at the end of the selection programme. The nucleus herd practising the COMBINED strategy experienced a negative response although the weaning weights were still heavier than those of animals selected using mass selection.

Generally the responses of weaning weight was slow during the first 10 years and was very rapid there after. The MASS strategy of selection resulted in a slow response of the phenotypic values, a steady (12 kg) response of the direct genetic values and steady decline (-10 kg) of the maternal breeding value. Selecting animals in the nucleus herd by applying the DIRECT strategy resulted in a decline of phenotypic response and direct genetic values in the first 6 years followed by a rapid response resulting in an overall response of 14 kg of the latter. The DIRECT strategy resulted in animals with the highest direct genetic values. However, maternal genetic values were always negative and declined steadily with time resulting in an overall decline of -7 kg. The MATERNAL and MATERNAL/DIRECT strategies had similar effects and had the highest maternal genetic values in the nucleus. Both strategies led to a steady increase of weaning weight during the first 10 years followed by a rapid response there after, resulting in an overall response of 8 kg. The response of direct genetic value increased during the first 10 years and subsequently declined. The overall change in direct genetic values was 4 and 3 kg for the MATERNAL and MATERNAL/DIRECT strategies, respectively. The COMBINED strategy produced the heaviest weaning weights during the first 8 years of selection. Animals selected using this strategy had the second highest direct genetic values with an overall response of 21 kg. The latter strategy resulted in a rapid decline in maternal breeding values after 10 years of selection resulting in an overall decline of -16 kg.

DISCUSSION

The responses to selection and the trends described in this study depend on the relative magnitudes of direct and maternal heritabilities. Baker (1980) illustrated how a large negative covariance between direct and maternal genetic effects results in a reduction in the expected response to selection. In this study strategies based on selection for maternal genetic effects (MATERNAL and MATERNAL/DIRECT) produced progeny with the heaviest weaning weights and the largest responses after 20 years of selection. Gerstmayr (1992) urged that if maternal heritability was higher than direct heritability, selection based on direct genetic values would lead to lower responses independent of the size and direction of the correlation. The responses to selection achieved through the DIRECT strategy were also significantly higher than was achieved through mass selection. The short term benefits of the COMBINED strategy were also described by Van Vleck, et al., (1977).

In practise the effectiveness of the appropriate strategies will depend on the efficiency with which maternal genetic values of the breeding animals are estimated. Maternal genetic effects are difficult to estimate since they are expressed one generation behind the direct genetic effects, are sex limited and are expressed late in life. Restricted maximum likelihood (REML) techniques using the relationship matrix are currently being used for estimating genetic values from performance records. Meyer (1991) has developed a derivative-free restricted maximum likelihood (DFREML) program that has been widely used for the estimation of genetic values of breeding animals using field records. A number of American beef associations now calculate maternal genetic values for weaned calves (Willham and Leighton, 1978). Similar mixed model techniques of evaluating breeding values need to be used in genetic improvement programs in Africa.

It is evident that application of selection when there is a negative correlation between direct and maternal genetic effects results in a decline in the other genetic effects. Since Mashona cattle and other indigenous breeds are suitable for use as maternal breeds, in commercial production systems, it is appropriate that they are selected for maternal performance through the use of breeding strategies that lead to an increase of maternal genetic values. Direct and maternal heterotic effects on pre-weaning gain have been shown to be large when there is extreme diversity in the development of the breeds. Such effects should be exploited by beef production systems in southern Africa.

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Table 1. Parameters (kg) used in the simulations to create populations of Mashona herds.

Parameter	Commercial herds	Testing herd	Small holder herds
Mean ± s.e	172 ± 28.0	150 ± 28.0	119 ± 35.9
Genetic distances	10	3	0
* $\sigma^2_{phenotype}$	371	371	477
σ^2_{direct}	90	90	116
$\sigma^2_{maternal}$	145	145	186
$\sigma_{direct/maternal}$	-32	-32	-40
σ^2_{error}	167	167	175

*Phenotypic variance in small holder farms was obtained by scaling the phenotypic variance of commercial herds by the ratio ($s.e_{smallholder}/s.e_{commercial\ herd}$)

Table 2. Responses of standardized weaning weight (± s.e) to different strategies used to select breeding animals in a simulated nucleus herd over a period of 20 years.

Selection strategy	Weight (kg)		
	First year	Final year	Response
Mass selection	32.8 ± 0.40[a]	40.3 ± 0.46[a]	7.5 ± 0.42[a]
Direct genetic value	31.0 ± 0.40[b]	42.1 ± 0.46[b]	11.2 ± 0.36[b]
Maternal genetic value	29.3 ± 0.40[c]	45.5 ± 0.46[c]	16.2 ± 0.36[c]
Combined[1]	47.1 ± 0.40[d]	41.8 ± 0.46[d,b]	-5.3 ± 0.40[d]
Maternal/direct[2]	29.4 ± 0.40[c]	44.8 ± 0.46[c]	15.4 ± 0.36[c]

[1]sires selected on direct genetic values and dams selected on maternal genetic values.
[2]animals selected first on the magnitude of their maternal genetic values then on their direct genetic values.
[a,b,c,d,e] Means within the same column with different superscripts differ significantly ($P<0.05$).