Selection Responses for Milk, Fat and Protein Yields in Zimbabwean Holstein Cattle

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ABSTRACT : One way of evaluating the effectiveness of a dairy breeding program is to measure response to selection. This may be direct or indirect. The objectives of this study were to estimate expected progress for direct selection on milk, fat and protein yields; to estimate the expected correlated responses on indirect selection for milk, fat and protein yields in Zimbabwean Holstein cattle and to establish the effect of selection intensity on responses. The Animal Model contained fixed effects of herd, year of calving, calving month, dry period, milking frequency and additive effects pertaining to cows, sires and dams. AIREML software package was used to analyse the data. The genetic and phenotypic parameters obtained in this study were used to compute direct and correlated responses to selection. Because of the higher heritabilities in first parity, genetic progress was found to be greater when selection was practised on first parity cows as compared to later lactations. It is therefore recommended that older cows in the herd be replaced with improved heifers so as to enhance genetic progress. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 7 : 883-887)*

Key Words : Response, Genetic Progress, Selection Intensity

INTRODUCTION

Breeding programmes have to be evaluated to identify optimum efficiency, and to predict possible rates of progress. It has, however, been realised that quantifying progress on genetic parameters alone is not sufficient and the current trend has been to follow up genetic evaluations with economic evaluations. Due to improvement in animal evaluation procedures over the past few decades, there has been consistent improvement in the genetic ability of the cow to produce milk (Hallowell et al., 1998a). Improvements in management techniques, better dairy equipment, improved feeding methods and more accurate record keeping have also led to improvements in the environmental or non-genetic effects on yields. Hallowell et al. (1998a) also suggested the need for future selection programmes to be based on a monetary value index taking fat and protein into account. Response to selection (R) is the difference in mean phenotypic value between the offspring of selected parents and the whole of the parental generation before selection. Correlated response refers to the response that is achieved in one trait as a result of selecting for another. The concept of correlated response suggests that it might sometimes be possible to achieve more rapid progress under selection for a correlated trait than from direct selection for the desired trait *per se* (Falconer, 1991). This is particularly true for reproductive traits with low heritabilities. The character on which selection is applied is termed the secondary character, but it should be noted that indirect selection cannot be expected to be better than direct selection unless the secondary character has a substantially higher heritability and the genetic correlation is high (Falconer, 1991). Indirect selection may, however, be preferable as in the following cases:

1. If the desired character is difficult to measure with precision, the errors of measurement may so reduce the heritability that indirect selection becomes advantageous.

2. If the desired trait is measurable in one sex only, but the secondary character is measurable in both, then a higher intensity of selection would be possible by indirect selection. All else being equal, the intensity of selection would be twice as great by indirect as by direct selection. A better plan would be to select one sex directly for the desired character and the other indirectly for the secondary character.

3. The desired trait may be costly to measure eg. protein yield. Then it may be better to select for an easily measured correlated character eg. milk yield.

Falconer (1991) noted that prediction of response is, in principle, valid for only one generation of selection. This is because the response is a function of heritability, hence responses in later generations cannot be predicted without re-determining the heritabilities in each generation.

The objectives of this study were to estimate expected progress for direct selection on milk, fat or protein yield; to estimate the expected correlated

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responses on indirect selection for milk, fat and protein yields in Holstein cattle and to establish the effect of selection intensity on responses.

MATERIALS AND METHODS

Milk recording in Zimbabwe

Milk recording in Zimbabwe follows the Statement Scheme which offers a quick comprehensive profile of the herd by presenting, at regular frequent intervals, reports containing progressive history of all cows in each herd. Two service options exist for herd owners, namely fully supervised and owner sampler. Fully supervised herds receive ten visits per year by Zimbabwe Dairy Services Association (ZDSA) milk recorders who carry out all the on farm testing procedures and dispatch milk samples, preserved with bronopol pills, and input forms to ZDSA central offices. Owner sampler herd owners on the other hand do their own testing and transportation of samples. Another form of owner sampling is group recording which is used for smallholder farmers. Owner sampler herds are tested twelve times a year, with milk recorders visiting four times a year to check on recording devices and animal identification. Herd owners record events occurring in their herds between test days such as calvings, deaths and disposals on the herd-event record forms. In addition, the farmer is required to keep cow identification and parentage information.

Laboratory testing is done at the central laboratory where milk samples are tested for butterfat and protein using a Bentley 2000 infra-red milk analyser. Somatic cell counts are determined by a counter. Samples are tested within three days of their arrival at the laboratory. Information on the input forms and the laboratory results are captured into the computer as soon as they reach the data processing unit.

Milk adjustments

There are no milk adjustment factors for Zimbabwe. The records which were used in this study were unadjusted milk records.

Selection procedure

Selection of cows and sires in Zimbabwe is based on breeding values predicted by best linear unbiased predictor (BLUP). These are computed by program AIREML (Gilmour, 1995). Foreign sires are selected on the basis of sire summaries in their countries of origin.

Direct and indirect responses to selection were calculated using genetic parameters (variances, heritabilities and correlations) obtained by Mandizha (1998).

Estimating genetic progress

1) Direct response to selection

Genetic progress R was calculated using the formula:

$$R=[(I_m+I_f)/(L_m+L_f)]*h^2*\sigma_p$$

where:
- R =annual rate of response to selection;
- I_m, I_f =selection intensity for males and females, respectively;
- L_m, L_f =generation interval for males and females, respectively;
- h^2 =heritability for the trait of importance;
- σ_p =phenotypic standard deviation.

The selection intensity (I) is a function of the proportion of animals selected to be future parents (p). In order that the effects of selection intensity on genetic progress may be established, two selection intensities were used for sires: I_m=1.755 (p=10%), and I_m=2.063 (p=5%), while that for dams was kept constant at I_m=0.424 (p=75%) for all lactation groups. Generation intervals were taken to be 2 years for males and 3 years for females. These were considered to be representative of current management practices in Zimbabwe.

2) Correlated response to selection

Correlated response was calculated using the following formula:

$$CR_X=ih_Xh_YrA_{XY}\,\sigma_{PY}$$

where: CR_X is the correlated response in trait X; h_X and h_Y are the square roots of the heritabilities of trait X and trait Y respectively; rA_{XY} is the genetic correlation between trait X and trait Y; σ_{PY} is the phenotypic standard deviation of trait Y as defined under direct response to selection.

RESULTS AND DISCUSSION

Heritability estimates for the three production traits were higher for first lactations when compared to later lactations (table 1). Muchenje (1996) also found this to be the case with milk yield in Zimbabwean Holsteins. Powell et al. (1981) noted that environmental variations in first lactation cows tend to be smaller than those in multiparous cows, hence the greater heritability estimates for first parity cows. The direct and indirect responses to selection are shown in tables 1 and 2.

Table 1. Heritabilities, phenotypic standard deviations and estimated direct genetic progress at two different selection intensities for milk, fat and protein yields

Parity	Trait	Heritability	Phenotypic SD	Genetic progress/yr (kg)*	
				i_m=1.755[a]	i_m=2.063[b]
1	Milk	0.34	1,964.9	291.1	332.3
	Fat	0.34	67.6	10.0	11.4
	Protein	0.30	62.3	8.1	9.3
2	Milk	0.22	1,720.4	164.9	188.3
	Fat	0.33	60.1	8.6	9.9
	Protein	0.25	53.9	5.9	6.7
3	Milk	0.17	2,058.0	152.5	174.0
	Fat	0.17	70.8	5.2	6.0
	Protein	0.19	64.0	5.3	6.0
4	Milk	0.10	2,048.6	89.3	101.9
	Fat	0.09	70.6	2.8	3.2
	Protein	0.07	62.6	1.9	2.2
5+	Milk	0.09	2,064.8	81.0	92.4
	Fat	0.10	72.1	3.1	3.6
	Protein	0.12	64.4	3.4	3.8

* Two scenarios are given: [a] Top 10% of the sires are selected; [b] Top 5% of sires selected.

Estimated genetic progress

This study indicated that rapid genetic progress in the production traits can be achieved by replacing cows in the herd with superior heifers. This is primarily due to the high heritability estimates for milk, fat and protein yields of first lactation cows. Muchenje (1996) observed a similar trend for milk yield in Zimbabwean Holstein cattle. Tables 1 and 2 show the genetic progress and correlated responses estimated using genetic parameters from this study. Selection responses were highest for first lactation cows for the three production traits. Selection of cows in first lactation is associated with the additional advantage of a shorter generation interval thus leading to increased genetic progress. Older cows should thus be replaced with improved heifers from superior sires. There may, however, be reduced accuracy due to lack of repeatability estimates for first lactation cows.

It should be noted that the rates of genetic progress achieved in this study were very high. This could be explained by the generally high variance components found in the study. Under the current ZDSA milk recording system, all cows are assumed to have an equal potential for reaching 305 days of lactation. If a cow dries off after 120 days of lactation but before 305 days, its yield is taken to represent the 305-day yield. If on the other hand, a cow is sold or dies after 120 days but before 240 days in lactation, its record is extended using Canadian adjustment factors to give a 305-day equivalent. These Canadian adjustment factors might not be appropriate for Zimbabwe. Any record above 240 days is taken as is and is not projected to a 305-day yield. Such a system is likely to result in too much variability within the data and may have led to the high variances obtained in this study.

Table 2. Estimated direct genetic progress (on diagonal) and correlated responses to selection (off-diagonal) (top 10% of sires and top 75% of cows selected)

Parity	Directly selected trait	Direct and correlated response (kg/yr)		
		Milk	Fat	Protein
1	Milk	291.1	9.2	7.7
	Fat	266.7	10.0	8.0
	Protein	251.0	8.3	8.1
2	Milk	164.9	6.1	5.9
	Fat	174.1	8.6	5.1
	Protein	163.0	6.6	5.9
3	Milk	152.5	4.3	4.7
	Fat	126.4	5.2	4.7
	Protein	150.6	5.1	5.3
4	Milk	89.3	1.3	1.2
	Fat	38.9	2.8	2.0
	Protein	66.0	1.4	1.9
5+	Milk	81.0	2.0	2.5
	Fat	57.7	3.1	2.6
	Protein	83.4	2.8	3.4

Van der Werf et al. (1989a) suggested that due to increased exchange of semen and embryos, dairy cattle data often reflect a mixture of genes from different populations. Hence the observed genetic effects in the resulting population may not be solely additive and may contain non-additive genetic effects, mainly dominance and epistatic effects. Estimators of variance components and additive genetic parameters might therefore be biased as well.

Hallowell et al. (1998a) noted that increased genetic gains can be attributed directly to greater importation of semen as well as the use of genetically superior, locally bred bulls. In addition, genetic change has been found to increase substantially with the availability of more accurate breeding values, the use of modern breeding value estimations, and increased awareness by dairy producers of the value of milk recording (Blanchard et al., 1983; Burnished et al., 1992).

A feature of the analyses in tropical countries is that the data are relatively few. Records may be affected by days in milk, illness, death or transfer of animals to another farm. Exclusion of short records could therefore mean that low producers were essentially removed from the analyses thereby possibly biasing estimates upwards. Ngere et al. (1973) clearly showed that the procedure of deleting short lactations, though customary, could lead to serious biases which could affect conclusions drawn about breeds, herds or regions.

Estimation of correlated response to selection

Owing to the positive genetic correlations among milk/fat, milk/protein and fat/protein, selection on any of these traits was found to result in a positive correlated response in the other two. The differences observed were in the magnitude of responses, this being a function of the heritabilities, genetic correlations and phenotypic standard deviations. This was in agreement with what has been reported elsewhere in literature (Hillers, 1984; Gibson, 1987; Schimdt, 1988; Weigel, 1997). In second parity, selecting directly for fat yield led to greater responses in milk yield than directly selecting for milk yield. For animals in second parity the responses on protein yield due to selecting indirectly for milk yield were similar to those obtained when selection was directly on protein yield. In fifth-and-later lactations direct selection on protein yield produced higher responses in milk yield than directly selecting for milk yield per se. Situations in which indirect selection is more effective than direct selection are very rare and many selection decisions would best be made by considering more than one trait and by predicting the total economic value (Van Vleck et al., 1987).

Hallowell et al. (1998b) noted the fact that heritability estimates for percentage traits are higher than those for absolute yields indicates that selection should be directed towards percentages. Nevertheless, this would result in large sacrifices in genetic gains for the yield traits due to the negative correlation between yield and percentage traits. Producers are thus advised to select on yield rather than percentages.

Ways of improving response

One way of improving selection response would be to increase heritability and this can be done by reducing the environmental variation through attention to the techniques of rearing and management, by multiple measurements, where possible, and to a limited extent, by assortative mating and increasing genetic variances through migrations, mutations or genetic drift.

Selection intensity could also be increased but this is limited by the reproductive rate of the organism under study because the proportion selected for breeding can never be less than that needed for replacement (Falconer, 1991). This would mean therefore that more intense selection can be applied to more prolific organisms. Because sires tend to have more offspring than dams, selection intensity in the former tends to be higher than in the latter.

In this study for instance, one sire had as many as 525 daughters. As shown in table 2, selection response was higher at the higher selection intensities for all production traits. Therefore, higher selection intensities can be used to achieve greater genetic progress. However, this should be done with great caution as it may lead to inbreeding.

Generation interval refers to the average time between the birth of an animal and the birth of its replacement. Very often there is a conflict of interest between selection intensity and generation interval. This is because the breeder can increase selection intensity, and hence response per generation, by waiting until more offspring are reared before implementing a selection decision. However, in so doing the generation interval inevitably increases, thus reducing the response per unit time. Hence, a compromise has to be struck between the desire for greater progress and the possible dangers associated with inbreeding. As with selection intensities, generation intervals for males and females tend to differ. What has to be maximised to achieve the greatest genetic gains is the ratio: $(i_m+i_f)/(L_m+L_f)$.

CONCLUSION

Heritability estimates for 305-day milk, fat and protein yields were highest in first lactation. This resulted in genetic progress being most rapid in this group of animals. Indirect selection can sometimes give greater response than direct selection. It is recommended that older cows should be replaced by improved first lactation cows. Greater genetic progress can be obtained by using higher selection intensities, provided this does not result in inbreeding. There is need to develop a selection index that incorporates milk, fat and protein yields if more genetic progress is to be made in Zimbabwe than is currently the case.

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