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# Evidence of a genotype by feeding level interaction in grazing Holstein-Friesian dairy cattle at different stocking rates

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## ABSTRACT

Lactation yields and estimated breeding values (EBVs) for protein, fat and milk were obtained for individual cows in a farmlet trial carried out at Dexcel in Hamilton, using Holstein-Friesian cows, to test for the existence of a genotype by environment interaction across the range of feeding levels, and EBVs typically found on New Zealand pasture-based dairy farms. At very low levels of feeding, with yields of 267 – 307 kg milksolids per cow (kg MS/cow), regression coefficients of lactation yield on EBVs were not significantly different from the expected value of 1. At high levels of feeding, with yields of 383 – 411 kg MS/cow, most of the regression coefficients for yields of protein, fat and milk on EBVs were significantly greater than 1. The results of this study show that at low levels of feeding the actual differences in production between cows, which differ in EBVs correspond to the actual differences in EBVs, whereas at high levels of feeding the difference in milk yields between genetic groups are greater than the difference in EBVs. This constitutes a form of genotype x environment interaction, in which genotype is measured as breeding values, and has important practical and economic implications for dairy farms, and for the expected value of genetic improvements.

**Keywords:** genotype; environment; interaction; Holstein-Friesian; pasture-based; breeding values; genetic merit.

## INTRODUCTION

Wide ranges of cow genotypes and feeding systems are now being used on New Zealand dairy farms. For example, breeds of cows include Holstein-Friesian (HF) (56%), HF/Jersey (J) cross (21%), J (15%), Ayrshire (1%) and others (7%) which include milking shorthorn, Guernsey and Brown Swiss (Livestock Improvement, 2001). There has also been an increase in the use of overseas genetics, so that by 1998, 38% and 9% of the genetic composition of HF and J cows respectively, was of overseas origin (Harris & Winkelman, 2000). Overseas animals are selected under intensive, high-input feed systems, many of which involve limited access to pasture (Mayne, 1998). This is very different from New Zealand, where animals are selected based on performance in pasture-based systems. A significant number of dairy farmers have changed from traditional low-input systems to high-input systems, resulting in large differences in feed intakes and milk yields per cow across the range of production systems. Therefore, it is important to determine if the phenotypic superiority of high genetic merit (HGM) cows is increased at higher levels of feeding, which would be a form of genotype x environment interaction (GxE).

Interaction between genotype and the effects of environment occurs when there are differences in the phenotypic expression of different genotypes between environments (Cromie *et al.*, 1998). A number of investigators have found significant GxE interactions in dairy cattle. In an Australian study, it was observed that, at low concentrate intakes, the difference in yield between two genetically different groups of cows was only half of what was predicted by the difference in estimated breeding values (EBVs). But, at medium and high intakes of concentrates, the differences in yields closely matched the differences in EBVs (Fulkerson *et al.*, 2000).

Similarly, Veerkamp *et al.* (1994) in Scotland, observed that for every 1-kg increase in predicted transmitting ability (PTA) for milksolids (MS), milk yield increased by 18 kg and 47 kg for animals fed low and high levels of concentrates, respectively. This represented a significant GxE interaction.

In a trial carried out in New Zealand by Kolver *et al.* (2002), New Zealand HF had slightly higher lactation yields than overseas HF on a fully-fed pasture-based system (465 vs 459 kg MS/cow, respectively). However, on a total mixed ration system the overseas HF had significantly higher lactation yields than New Zealand HF (720 & 602 kg MS/cow, respectively).

In contrast, several Irish studies cannot find significant interactions between genotype and feeding environment (Buckley *et al.*, 2000; Gordon *et al.*, 1995; O'Connell *et al.*, 2000). However, the authors observed that lack of definite GxE interactions in animal trials may have been due to the small differences between genotypes and/or feeding systems, short trial duration and small numbers of cows.

The objective of the present study was to determine if there are interactions between genotype and feeding level across the range of feeding levels, and EBVs typically found on New Zealand pasture-based dairy farms.

## MATERIALS AND METHODS

Lactation yields were obtained for individual cows at Dexcel, in Hamilton (seasons 1999/2000 and 2000/2001) using mixed-age HF cows (Macdonald *et al.*, 2001). Live weights and EBVs for fat, protein, milk and liveweight (Lwt) for individual cows were obtained at the start of the trial. There were 25-33 cows in each of the four feeding level groups, with stocking rates of 2.2 cows/ha (1100 kg Lwt/ha), 2.7 cows/ha (1350 kg Lwt/ha), 3.2 cows/ha (1600 kg Lwt/ha), and 3.7 cows/ha (1850 kg Lwt/ha), respectively. The system was pasture-based, with no imported feed. EBVs for fat, protein, milk and Lwt were 28.8, 26.5, 800 and 52.5 kg, respectively.

## STATISTICAL ANALYSIS

The data set was analysed using the PROC MIXED procedure of SAS (2001). For each variable studied, the

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model included the effects of age, feeding level, experimental year, the interaction between feeding level and experimental year, and the co-variables calving day after the herd's commencement of calving and the EBV nested in each feeding level and experimental year. The regression coefficients of adjusted phenotypic observations on EBVs were tested to see if they departed from the theoretical value of 1. Milksolids yields (adjusted for the model effects) were also analysed by regression against milksolids EBVs, to test for significant differences between the highest and lowest feeding levels.

## RESULTS

The stocking rates used resulted in different feed intakes in each treatment. The feed intakes for the Holstein-Friesian cows were 5060, 4647, 4373, and 4014 kg DM/cow/year for the high, medium, low and very low feeding levels, respectively based on the differences between pre and post grazing herbage mass throughout the two years of the trial (Macdonald *et al.,* 2001).

Least squares means of lactation yields for fat, protein and milk, and EBV for milksolids at each feeding level are presented in Tables 1. As expected, milksolids yields per cow were highest at the high feeding level (383 and 411 kg MS/cow, for the 99/00 and 00/01 seasons, respectively), and were lowest at the very low feeding level (267 and 307kg MS/cow, respectively). The lactation yields at the very low feeding level are slightly lower than the average production in New Zealand of 310 kg MS per cow (Livestock Improvement, 2001). The differences in milksolids yield per cow between feeding level groups were all significant. The least squares means of milksolids EBVs and the ranges were not different between each feeding-level group.

The regression coefficients for the relation between adjusted lactation yields for protein, fat and milk and the respective EBVs for protein, fat and milk, are presented in Table 2. At the high feeding level, most of the regression coefficients were significantly greater than 1. At the medium, low and very low feeding levels most of the estimates of the regression coefficient of yields on the respective EBVs, were not significantly different from the expected value of 1.

The result for the regression of adjusted milksolids

**TABLE 1:** Lactation yields (Means ± S.E) for milk, fat, protein and milksolids of Holstein-Friesian cows at four different levels of feeding

| Level of feeding(stocking rate) | High (2.2 cows/ha) | Medium (2.7 cows/ha) | Low (3.2 cows/ha) | Very Low (3.7 cows/ha) |
|---|---|---|---|---|
| Production (99/00) | | | | |
| Milk (kg/cow) | 4682 ± 88.2 [a] | 4078 ± 86.0 [b] | 3647 ± 89.3 [c] | 3314 ± 85.0 [d] |
| Fat (kg/cow) | 215 ± 4.1 [a] | 188 ± 4.2 [b] | 169 ± 4.1 [c] | 152 ± 3.9 [d] |
| Protein (kg/cow) | 168 ± 2.9 [a] | 144 ± 2.8 [b] | 128 ± 2.9 [c] | 115 ± 2.8 [d] |
| Days in Milk | 291 ± 2.8 [a] | 278 ± 2.7 [b] | 244 ± 2.8 [c] | 233 ± 2.6 [d] |
| Milksolids (kg/cow) | 383 ± 6.9 [a] | 332 ± 6.8 [b] | 297 ± 6.8 [c] | 267 ± 6.6 [d] |
| Milksolids EBV (kg) | 56 ± 2.3 [a] | 59 ± 2.3 [a] | 54 ± 2.3 [a] | 54 ± 2.2 [a] |
| Range | 33 to 78 | 37 to 87 | 22 to 74 | 30 to 78 |
| Production (00/01) | | | | |
| Milk (kg/cow) | 4976 ± 107.2 [a] | 4471 ± 99.2 [b] | 4071 ± 86.0 [c] | 3787 ± 97.0 [d] |
| Fat (kg/cow) | 235 ± 4.8 [a] | 206 ± 4.5 [b] | 193 ± 5.2 [b] | 176 ± 4.5 [c] |
| Protein (kg/cow) | 177 ± 3.7 [a] | 157 ± 3.4 [b] | 143 ± 3.8 [c] | 131 ± 3.4 [d] |
| Days in Milk | 295 ± 2.6 [a] | 280 ± 2.4 [b] | 271 ± 2.8 [c] | 250 ± 2.4 [d] |
| Milksolids (kg/cow) | 411 ± 8.3 [a] | 363 ± 7.9 [b] | 336 ± 8.9 [c] | 307 ± 7.7 [d] |
| Milksolids EBV (kg) | 57 ± 2.2 [a] | 58 ± 2.1 [a] | 55 ± 2.3 [a] | 57 ± 2.0 [a] |
| Range | 33 to 84 | 37 to 87 | 31 to 74 | 38 to 78 |

[abc] means with different superscripts within a row significantly different (P<0.05)

**TABLE 2:** Regression coefficients of lactation yields for milk, protein, fat and milksolids, on respective estimated breeding values (EBV) at four different levels of feeding in Holstein-Friesian cows

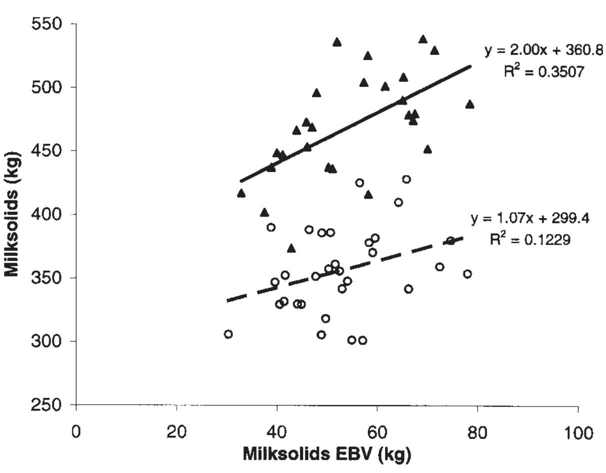
| Season | 1999/2000 | 2000/2001 |
|---|---|---|
| **High Feeding Level** | | |
| Milk yield/Milk EBV | 1.86 ± 0.330* | 2.01 ± 0.343* |
| Protein yield/Protein EBV | 2.17 ± 0.472* | 2.15 ± 0.532* |
| Fat yield/Fat EBV | 1.91 ± 0.589 | 2.59 ± 0.641* |
| Milksolids yield/Milksolids EBV | 2.00 ± 0.555 | 2.40 ± 0.616* |
| **Medium Feeding Level** | | |
| Milk yield/Milk EBV | 1.71 ± 0.454 | 1.94 ± 0.430* |
| Protein yield/Protein EBV | 1.64 ± 0.524 | 1.70 ± 0.579 |
| Fat yield/Fat EBV | 0.92 ± 0.630 | 0.97 ± 0.678 |
| Milksolids yield/Milksolids EBV | 1.08 ± 0.630 | 1.08 ± 0.716 |
| **Low Feeding Level** | | |
| Milk yield/Milk EBV | 0.86 ± 0.457 | 1.49 ± 0.546 |
| Protein yield/Protein EBV | 0.59 ± 0.426 | 1.35 ± 0.633 |
| Fat yield/Fat EBV | 0.92 ± 0.524 | 2.19 ± 0.780 |
| Milksolids yield/Milksolids EBV | 0.73 ± 0.485 | 1.70 ± 0.748 |
| **Very Low Feeding Level** | | |
| Milk yield/Milk EBV | 0.89 ± 0.428 | 1.78 ± 0.425 |
| Protein yield/Protein EBV | 0.77 ± 0.573 | 1.51 ± 0.596 |
| Fat yield/Fat EBV | 1.48 ± 0.495 | 1.64 ± 0.733 |
| Milksolids yield/Milksolids EBV | 1.07 ± 0.578 | 1.53 ± 0.750 |

*significantly different to the theoretical value of 1 (P<0.05) yields on milksolids EBVs at the two extreme feeding levels, high and very low, for the 1999/2000 season is presented in Figure 1. At the very low feeding level, the regression coefficient of milksolids yields on milksolids EBVs was 1.07, and at the high feeding level, the regression coefficient was 2.00, but is not significantly different from 1. The data for the 2000/2001 season, also shows the same relationship with the regression coefficient greater at the highest feeding level (2.40 which is significantly different to 1), than at the lowest feeding level (1.53 which is not significantly different to 1; Table 2). The differences between the regression coefficients of each group for each season were not significantly different due to the small number of cows per group, which ranged from 25-33 cows. Overall the results indicate a GxE interaction where increases in milk yields caused by increases in feeding level are greater in cows of high genetic merit than in cows of lower genetic merit.

## DISCUSSION

The evidence for a GxE interaction reported in the current study with grazing cows can be compared with the results of other trials. In Australia, Fulkerson *et al.* (2000) found that at medium and high intakes of concentrates, the actual differences in milk yields corresponded to the difference predicted from milksolids EBVs, whereas at low feeding levels the difference in yields is only half of what was predicted from EBV differences. Cromie *et al.* (1998), using records from commercial herds in Ireland, observed that bull proofs obtained from systems that used high levels of concentrates, over-predicted genetic merit for cows managed in systems that used lower levels of concentrates, and a similar conclusion was made from the results of an Irish experiment (Kennedy *et al*., 2002). In Scotland, Veerkamp *et al.* (1994) reported the regression coefficients of milksolids yields on milksolids PTA at low and high concentrate feeding levels of 1.35 and 2.53 (theory = 2), respectively, although the difference was not statistically significant over a 26-week trial period. The results of the present study, along with other published results, show that GxE interactions are present amongst dairy production systems. High feeding levels allow a cow's genetic potential to be fully expressed, whereas at low feeding levels, this ability is compromised (Kennedy *et al.*, 2002).

**FIGURE 1:** Regression of milksolids yield on milksolids estimated breeding value (EBV), at high (——) and very low (- - - -) feeding levels of Holstein-Friesian cows for the 1999/2000 season




The results also illustrate that HGM cows achieve greater responses than low genetic merit (LGM) cows when feed intakes per cow are increased. Similar results were found in New Zealand by Grainger *et al.* (1985), who observed that HGM cows achieved greater responses to an increase in feeding level (63 vs 50 g extra milksolids per kg DM of pasture offered for HGM and LGM, respectively). In the current study, feed intakes per cow were increased by managing cows under low stocking rates, however, it is also possible to increase feed intakes per cow through the use of supplements. For example, Fulkerson *et al.* (2000) found that at medium concentrate intakes (0.84 t DM/cow), HGM and LGM cows achieved responses of 105 and 86 g MS per kg of extra concentrate offered, respectively over the course of the lactation. Similarly, Kennedy *et al.* (2002) observed responses of 63 and 72 g MS/ kg DM concentrate, for HGM cows changing from low to medium and from low to high levels of concentrates, respectively, whereas the corresponding values for medium genetic merit cows were lower, 50 and 54 g MS/kg DM concentrate. The larger responses to extra feed achieved by HGM cows is partly due to their ability to partition a higher proportion of their dietary energy intakes towards milk, and less to liveweight gain (see Bryant *et al.*, 2003). These results have important practical implications for dairy farmers, as higher responses to additional feeds would enable the increased and profitable use of a greater range of supplements when these are fed to HGM dairy cows.

The system for the genetic evaluation of dairy cattle adjusts for heterogeneous variance (Harris *et al.*, 1996), and this accounts for the type of GxE interaction described in the current study. Each individual cow record is adjusted to provide an accurate representation of the genetic merit of an animal across a range of production systems within New Zealand. Consequently, animals with high EBVs for milk components will have the same ranking relative to other cows irrespective of the type of system in which they are managed. However, Cromie *et al.* (1998) in Ireland, found evidence of re-ranking of sires for milk and protein yield in herds with very low yields, and it is possible that re-ranking could occur in New Zealand dairy systems with either very low or very high feeding levels (Lopez-Villalobos *et al.*, 1994).

## CONCLUSION

The EBVs provide a good indication of the expected performance of cows in average New Zealand herds. At high feeding levels, greater milksolids responses are achieved than is indicated by the differences in EBVs among animals or herds. In addition, higher feeding levels or greater supplement use may be needed to fully exploit the benefits of genetic gain within the herd, although profitability will still depend on the cost of the extra feed and the value of the extra milk.

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