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Crossbred cows exceed production expectation in high-producing herds

WA Montgomerie

293 Forrest Road, RD1 Cambridge, New Zealand 3493
**Corresponding author. Email: montgobill@gmail.com*

Abstract

New Zealand dairy production per cow has increased by over 33% in the past fifteen years. Consequently, animal breeders are interested in understanding how expression of heterosis for dairy production traits is affected in higher-production systems. To investigate this question a natural-experiment approach was taken, utilising herd-testing records in the 2010-11 dairy production season in herds that contained two breeds, Holstein-Friesian cows ('control' breed) and Holstein-Friesian x Jersey cows ('treatment'). Herds were divided into two production system classes. The system classes were national-average herd production per cow ('control' system) and high per cow production ('treatment'). Per cow yields were over 45% higher in the treatment herds than in national-average herds. Herd test records were analysed for 29,329 two-year-old heifers, and for 20,753 five-or six-year-old mature cows. Dependent variables for the statistical models were deviations from contemporary group means for 270-day yields for production traits. Explanatory variables included Breed, System, and individual cow Production Values as estimated in the national genetic-evaluation system (which include genetic, permanent environment and heterosis effects on yields). In the high-performance production systems the crossbred cows had higher yields than the Holstein-Friesian cows (compared with Production Value predictions) by 5.7 kg milksolids (heifers) and 1.9 kg milksolids (mature cows). This study indicates that heterosis for dairy production traits is more fully expressed in production systems that favour higher per cow yields than in the more restrictive production systems common in the 1990s.

Keywords: heterosis; multibreed; dairy production; genotype-by-environment interaction

Introduction

Historically, crossbreeding has been used as a means to generate resilient farm animals for farm-production systems that experience frequent environmental disturbances, and which are, in this sense, more stressful than those in which the parent lines have been developed (Barlow 1981). More recently, many crossbred farm animals have been generated for highly controlled farm-production systems, in which the environment has been designed and managed to support continuous high expression of the animals' genetic potential. A New Zealand example is the breeding for poultry meat (PIANZ 2010).

The grazing environment for New Zealand dairy cows is subject to multiple disturbances that are outside the farmers' control. The search for resilient cows has resulted in crossbred cows making up forty-two percent of the national dairy herd, while straight-bred Holstein-Friesian cows make up thirty-seven percent (DairyNZ 2013). In the past decade, farmers have been able to exercise more control over environmental disturbances as larger quantities of supplementary feeding have become economically available, and irrigation systems have evened out fluctuations in pasture quality and supply. In the dairy season commencing in 2001, five percent of dairy herds exceeded 400 kilograms of milksolids per cow (Livestock Improvement 2002). By 2011 over twenty-eight percent of herds exceeded that level of per cow production (DairyNZ 2012). A significant question for managers of these herds of higher-producing cows is the suitability of crossbred cows for their production systems. Producers operating these more-intensive production environments often prefer breeding plans that feature high usage of Holstein sires originating in the intensive production environments in the Northern Hemisphere such as North America and the Netherlands (Bryant 2007a).

An analysis of New Zealand dairy production records between 1989 and 2003 has shown suppression of heterosis in very-low-yield environments (Bryant 2007b). To investigate more recent expressions of heterosis on production traits, a natural-experiment approach was taken for this study, utilising herd-testing records in the 2010-11 dairy production season in herds that contained both Holstein-Friesian (H-F) cows and Holstein-Friesian x Jersey crossbred (XB) cows. The natural-experiment approach to data analysis is common in the econometric literature, making use of serendipitous situations where assignment to treatment approximates randomized design or a well-controlled experiment (DiNardo 2008). It enables effective use of large volumes of data in the LIC National Database, without the requirement for costly controlled experiments necessarily limited to small numbers of animals.

Materials and methods

Herd-level data

Herd-level data was extracted from the LIC National Database for herds that had been herd tested at least four times in the 2010-11 dairy season, had at least 300 tested cows, and exceeded 200 days in milk

Figure 1 The frequency of groups of two-year-old herd-mate contemporaries, when divided into classes based on the percentage of Holstein-Friesian heifers within the group.

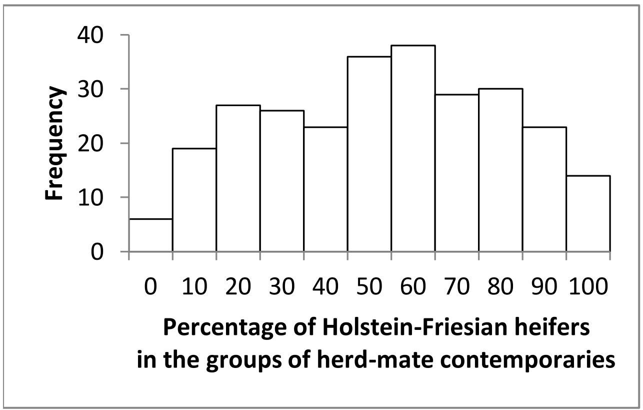
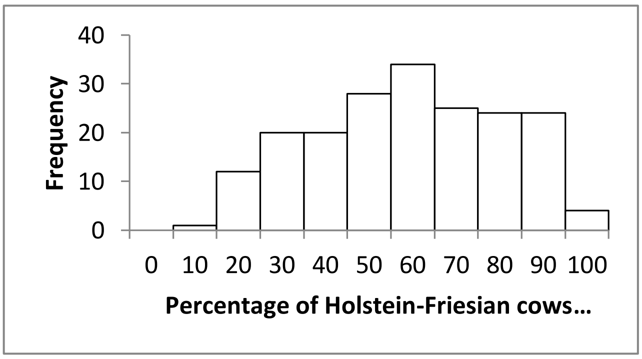


Figure 2 The frequency of groups of mature herd-mate contemporaries, when divided into classes based on the percentage of Holstein-Friesian cows within the group.



for the recorded lactations on average. The 2010-11 dairy season was selected because national per cow production was very close to the twenty-year trend-line in that season. The specified criteria were met in 2,726 herds. Each of these herds was allocated to a herd breed class, derived from the breed composition of the cows in the herd. Herds with average milksolids per cow production at least 1.6 standard deviations higher than the class mean were designated as High-Performance-system (HP) herds. Herds within ±0.2 standard deviations of the class mean were designated as Average system (AVE) herds. The subsequent statistical analysis of individual cow data featured these two classes for production system, with AVE as the conceptual 'control' and HP as the 'treatment'.

Individual cow data

Breed. Data analysis was restricted to two breed classes. H-F animals were defined as those with at least fourteen sixteenths identified H-F ancestry. XB animals were defined as those with only H-F and Jersey animals in their pedigree and with less than fourteen sixteenths of single-breed ancestry. The analysis featured these two breed classes, with H-F as the conceptual 'control' and XB as the 'treatment'. On average, the ancestral H-F breed proportions were respectively fifteen and nine sixteenths for the animals in the H-F and XB breed classes.

Two-year-old heifers. Individual heifer data was analysed from 102 HP and 169 AVE herds that had at least 15% of both H-F and XB cows. There were 29,329 heifers of these breeds included in the study. They calved in the period June to September, and had both recorded lactations and recorded sires. There were 15,692 XB heifers and 13,637 H-F heifers. Figure 1 is a histogram showing frequencies for classes of contemporary groups based on percentage of H-F heifers within the group. Average yields were 420 kg milksolids for the heifers in the HP herds, and 303 kg for the heifers in the AVE herds.

Mature cows. Individual cow data was analysed from 104 HP and 88 AVE herds. There were 20,753 cows included in the study. They were five or six years of age, had calved in the period June to September, and had both recorded lactations and recorded sires. There were 10,044 XB cows and 10,709 H-F cows. Figure 2 is a histogram showing frequencies for classes of contemporary groups based on percentage of H-F mature cows within the group. Average yields were 555 kg milksolids for the cows in the HP herds, and 417 kg for the cows in the AVE herds.

Lactation Yield Deviations. The dependent variables for the statistical analyses were Lactation Yield Deviations (LYD) for protein, fat and volume. LYD is the best estimate of an animal's current lactation deviation from contemporary group mean. The measures are adjusted for effects of stage of lactation on test days, are standardised to common lactation lengths for all animals, and scaled such that LYD variance is the average of the variance of the first four lactations (Johnson 1996).

Production Index

Individual Production Values report animal productive merit as estimated in the national genetic-evaluation system, including genetic, permanent environment and heterosis effects on yields (Harris et al. 2007). These were extracted from the May 2011 national genetic-evaluation, and re-based to zero means for the heifers included in the study, and likewise for the mature cows. For this report the re-based estimates are called Production Index (PI). It was necessary to include these continuous dependent variables in the statistical analysis to avoid confounding System and Breed effects with effects of individual animal merit.

Nuisance factors

Anticipated nuisance factors included cow age at calving (in days), which was nested within year of birth (YOB) for the mature cows. Age at calving was constructed as deviation from the mean of all the study animals in the age group, with the mean set to zero. Herd was included in the multiple regressions to account for factors such as difference in breed proportions in the groups of contemporaries.

Table 1 Regression coefficients and the standard errors of the coefficient estimates with associated P values for factors affecting dairy production performance of 29,329 two-year-old heifers in the 2010-11 dairy season for yields of protein (kilograms), fat (kilograms), and volume (litres). Breed had two classes with Holstein-Friesian coded 0 and Crossbred (XB) coded 1, so the coefficient reports the differential impact on performance of Crossbred compared with Holstein-Friesian. System had two classes with the average per cow performance system coded 0 and the high-performance system coded 1, so the coefficient reports the differential impact of the high-performance system (noting that the performance records have been pre-adjusted for heterogeneous variance). Production Index (PI) was trait Production Value extracted from the May 2011 national genetic evaluation, re-based to zero mean for the heifers included in the study.

Trait	Factor	Coefficient	SE	P value
Protein	Breed (β_1)	3.68	0.07	<0.001
	System (β_2)	2.35	0.49	<0.001
	XB & HP interaction (β_3)	0.28	0.11	0.011
	PI (β_4)	1.043	0.003	<0.001*
	PI & XB interaction (β_5)	-0.041	0.004	<0.001
	PI & HP interaction (β_6)	0.006	0.004	0.12
	Age at calving (β_7)	0.034	0.001	<0.001
Fat	Breed (β_1)	2.01	0.09	<0.001
	System (β_2)	-1.34	0.64	0.035
	XB & HP interaction (β_3)	-0.269	0.14	0.055
	PI (β_4)	1.024	0.003	<0.001*
	PI & XB interaction (β_5)	0.008	0.004	0.034
	PI & HP interaction (β_6)	0.015	0.004	<0.001
	Age at calving (β_7)	0.039	0.001	<0.001
Volume	Breed (β_1)	158.4	2.57	<0.001
	System (β_2)	76.5	16.75	<0.001
	XB & HP interaction (β_3)	12.0	3.90	0.002
	PI (β_4)	0.984	0.003	<0.001*
	PI & XB interaction (β_5)	-0.068	0.004	<0.001
	PI & HP interaction (β_6)	0.001	0.004	0.892
	Age at calving (β_7)	0.81	0.03	<0.001

*tested against $\beta_4 = 1$

Statistical methods

Linear regressions (Minitab Inc. 2000) were conducted with LYDs as the dependent effects. With three production traits and two age groups there are six regressions to report. In the case of the heifer regressions the explanatory variables were the differential breed effect for XB (β_1), the differential system effect for HP (β_2), the XB and HP interaction (β_3), the PI effect (β_4), the PI interaction with XB (β_5), the PI interaction with HP (β_6), and age deviation within YOB (β_7). In each of the regressions the herds to which the animals belonged was fitted as a fixed effect, apart from two herds (to enable matrix inversion). The individual herd effects are not reported, nor are the constant terms (β_0). The explanatory variables for the mature cow regressions were the same as for the heifer regressions, except that age at calving was treated differently to cope with the two birth years in that data set. YOB had two classes with YOB 2005 coded zero, and YOB 2004 coded one. The regression coefficient of primary interest was YOB (β_7). Of lesser interest (and not reported) were the very small coefficients for age deviation within YOB (β_8 and β_9).

Results and discussion

The data extract for this study did not include full pedigree of the animals. Also, design of the extract meant that very few of the contemporary groups in either the AVE or HP herds had useful numbers of Jersey animals. Consequently the final data extract excluded Jersey cows, cows of red breeds, or three-way crossbreds. Without data for both parent breeds, it was not possible to derive XB heterosis estimates. However, the PI covariates represented effective exogenous information about XB heterosis effects and enabled testing of hypotheses about expression of heterosis for dairy production traits in the current higher production systems that characterise the industry.

The heifer regression coefficients and standard errors are reported in Table 1. The mature cow regressions are reported in Table 2. The reported P values are for coefficient difference from zero, apart from PI where the expected coefficient was one.

For this 2010-11 data the XB heifers' contemporary comparisons were 5.7 kg milksolids higher than for H-F heifers compared with Production Value predictions from the national genetic-evaluation system. This magnitude of phenotypic performance in excess of expectations was also observed for XB heifers in the HP production systems.

The XB mature cows' contemporary comparisons were 1.3 kg milksolids higher than for H-F cows compared with Production Value predictions from the national genetic-evaluation system. This magnitude of phenotypic performance in excess of expectations increased to 1.9 kg for XB cows in the HP production systems. A larger magnitude for the heifers than for the mature cows is consistent with the earlier maturity of the XB cows.

Table 2 Regression coefficients and the standard errors of the coefficient estimates with associated P values for factors affecting dairy production performance of 20,753mature cows in the 2010-11 dairy season for yields of protein (kilograms), fat (kilograms), and volume (litres). Breed had two classes with Holstein-Friesian coded 0 and Crossbred (XB) coded 1, so the coefficient reports the differential impact on performance of Crossbred compared with Holstein-Friesian. System had two classes with the average per cow performance system coded 0 and the high-performance system coded 1, so the coefficient reports the differential impact of the high-performance system (noting that the performance records have been pre-adjusted for heterogeneous variance). Production Index (PI) was trait Production Value extracted from the May 2011 national genetic evaluation, re-based to zero mean for the cows included in the study. Year-of-birth (YOB) had two classes with 2005 coded 0 and 2004 coded 1, so the coefficient reports the differential impact of being six years of age compared to five years.

Trait	Factor	Coefficient	SE	P-value
Protein	Breed (β_1)	0.75	0.25	0.003
	System (β_2)	-0.14	1.27	0.914
	XB & HP interaction (β_3)	0.56	0.34	0.101
	PI (β_4)	0.992	0.010	0.413*
	PI & XB interaction (β_5)	-0.000	0.011	0.990
	PI & HP interaction (β_6)	-0.033	0.011	0.003
	YOB, 6 years of age (β_7)	1.040	0.157	<0.001
Fat	Breed (β_1)	0.54	0.34	0.115
	System (β_2)	3.96	1.74	0.023
	XB & HP interaction (β_3)	0.08	0.46	0.863
	PI (β_4)	0.953	0.010	<0.001*
	PI & XB interaction (β_5)	0.016	0.011	0.156
	PI & HP interaction (β_6)	-0.019	0.012	0.101
	YOB,6 years of age (β_7)	1.702	0.216	<0.001
Volume	Breed (β_1)	29.51	7.90	<0.001
	System (β_2)	-124.19	38.40	0.001
	CRO & HP interaction (β_3)	7.19	10.81	0.506
	PI (β_4)	1.007	0.009	0.453*
	PI & XB interaction (β_5)	-0.019	0.010	0.049
	PI & HP interaction (β_6)	-0.035	0.010	<0.001
	YOB, 6 years of age (β_7)	26.758	4.759	<0.001

*tested against $\beta_4 = 1$

The PI coefficient had a unity expectation given the centring methods and the similar heterogeneous variance adjustments used in the derivations of LYD and PI. While this expectation was met in only two cases, the departures from expectation would not be expected to bias the breed intercept coefficients. The age at calving effects were in line with prior expectations.

The irregular pattern of the HP system coefficient estimates warrants comment. The effects of production system on individual cow performance are removed in the derivation of LYDs. Consequently this study cannot be used to support inferences about system impacts on trait performance.

The principal purpose of this study was to investigate with up-to-date data the previous indications in the work of Bryant that expression of heterosis was suppressed in herd environments where per cow milksolids yields were in the order of 225 kg annually when compared with environments where yields were in the order of 300 kg. Bryant was working with data for two year old heifers from 1989 to 2003. Herd environments have changed noticeably since then, so that the question of greater current interest is not whether heterosis expression is suppressed in very low yield environments but whether heterosis is more fully expressed in the current environments that are more favourable to higher yields. Estimates for breed and heterosis effects in the national genetic-evaluation system are derived from all the herd test data since 1986. Consequently, heterosis expectations are partially conditioned by performance in harsher environments for production yields during the late 1980s and the 1990s. Both the AVE and HP environments in 2010-11 were noticeably more favourable for higher per cow yields than the average environments before 2000. The indications from the current study that recent production environments enable fuller expression of heterosis effects suggests that it would be advisable to test for environmental impacts on national genetic-evaluation by periodically cutting off performance data from earlier years. This might be an efficient way to ensure that genetic estimates are as relevant to current production circumstances as possible.

It should be noted that the current study does not extend to analysis of liveweight, due to lack of liveweight records for the studied cows. It is plausible that there is fuller expression of heterosis for liveweight in the environments that favour higher milk and milksolids yields. Simply extrapolating from this study to conclusions about productive efficiency as reported in the Production Worth index would not be warranted.

Conclusion

Evidence from the 2010-11 dairy production season is consistent with the conjecture that heterosis for yield traits is more fully expressed in the higher production environments that characterise current New Zealand dairy production than in the more restrictive production environments of earlier decades. The evidence does not support the common conjecture that Holstein-Friesian cows are relatively better suited to high-input farming systems in New Zealand than Holstein-Friesian x Jersey crossbred cows.

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