THE EFFECT OF GENOTYPE X ENVIRONMENT INTERACTION ON PREDICTED DOLLAR RESPONSE UNDER INDEX SELECTION

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SUMMARY
The effect of genotype x environment (GxE) interaction on response to selection for an index with an unrestricted breeding objective was investigated. It was assumed that wool sheep were selected in a stud environment to genetically improve animals kept under commercial conditions taking a known GxE interaction into account. The genetic correlations between the same traits expressed in two different environments were changed in a systematic manner to express different levels of GxE interaction. Large GxE interactions led to a 75% reduction in predicted dollar response. Estimates of genetic correlations obtained from real data ranged from 0.50 to 0.76. Under these conditions, the effects of GxE interaction reduced the economic response to selection ($/generation) by about 50%.

Keywords: Genotype x environment interaction, selection index, genetic correlation.

INTRODUCTION
The basis for genetic progress of commercial Merino flocks are selection decisions made on rams in the stud flocks from which commercial producers buy breeding stock. Genotype x environment (GxE) interactions can act on the performance of animals in a commercial production environment, which are offspring of sires that were selected on their phenotypic records under stud conditions. GxE interactions can alter the ranking of genotypes in one environment compared to a different environment and can hinder response to selection (Dickerson 1962).

In selection indices objective traits and selection criteria are often in fact not the same but correlated traits. Leading on from Falconer’s (1952) approach of treating the same trait expressed in two environments as genetically different but correlated traits, such ‘same trait’ selection criteria and breeding objective traits are not the same if animals are selected in one environment to genetically improve a flock in a different environment. They become different but correlated traits.

The aim of this study is to investigate the influence of a known GxE interaction on dollar response in a Western Australian wool-farming situation. The basic assumption is that selection decisions are made in a stud environment for the genetic improvement of sheep in a commercial production environment taking the effects of known GxE interactions into account.

MATERIAL AND METHODS
A selection index was constructed that aims at the improvement of the production traits in a commercial flock, which purchases rams from the stud flock under selection. A GxE interaction occurs between the stud and commercial environment and therefore selection criteria and breeding objective traits are treated as different but correlated characters. The genetic correlations between the same traits in different environments are assumed to be known. The phenotypic and genetic
correlations and heritabilities were estimated from the data collected in Wool Tenderness Project (Dominik et al. 1999), in which two groups of sheep were kept under different nutrition levels in Western Australia. They are assumed to represent stud and commercial production conditions respectively. The degree of GxE interaction that was found between different traits expressed in the different environments was discussed by Dominik et al. (2001).

The breeding objective involved a positive economic weight for clean fleece weight (cCFW), a negative weight for fibre diameter (cFD) and a positive weight for staple strength (cSS) and body weight (cBWT), all traits expressed in the commercial environment (‘c’). The selection criteria in the breeding flock were clean fleece weight (sCFW), fibre diameter (sFD), body weight (sBWT) and coefficient of variation of fibre diameter (sCVFD) expressed in the stud flock (‘s’).

A function \( f(k) \), with \( k \) ranging from -1 to +1 in steps of 0.1, was used to produce a range of correlations that express different sizes of GxE interaction. Only the genetic correlations that show the relationship between the same traits in two environments were altered to be able to relate the results to GxE interactions effect as defined by Falconer (1952). The altered correlations \( (r_G') \) were calculated as follows and can be seen in Figure 1.

\[
f(k) = r_G' = k + (1 + k)(1 - k)(r_G - k) + z
\]

where \( z = (k^2 * (1 - k)) \) for \( k > 0 \), and \( z = (k^2 * (-1 - k)) \) for \( k < 0 \).

**RESULTS AND DISCUSSION**

The values of the genetic correlations of the same trait expressed in two different environments as a function of \( k \) are shown in Figure 1. The value \( k \) ranged from 1 (no GxE interaction, all relevant \( r_G = 1 \)), through 0, which indicates the GxE interaction as estimated from the data set, to -1 (extreme GxE interaction, all relevant \( r_G = -1 \)). The degree of non-linearity of \( f(k) \) was determined by the correlations estimated from the real data at \( k = 0 \) with the restriction that all correlations between the traits had to be \( r_G' = 1 \) at \( k = 1 \) and \( r_G' = -1 \) at \( k = -1 \). From \( k = -0.6 \) downwards the genetic correlations started to become negative. The weakest genetic correlations were generated between \( k = -0.5 \) and \( k = -0.7 \). As a result of the method of alteration of the genetic correlations the G-matrix was inconsistent from \( k = -0.8 \) to \( k = -1 \).

Other studies on data analysis of wool and body weight traits of sheep suggest that the genetic correlations range mainly from highly positive to lowly negative estimates (Woolaston 1987). Therefore the most important results for the effect of GxE interactions on genetic and dollar response ranged, in this case, between \( k = 1 \) and \( k = -0.7 \), which translates into correlations equal to 1 through to lowly negative genetic correlations between the same traits in different environments.

Figure 2 illustrates the predicted dollar responses per year for the different traits and the total dollar response for all values of \( k \). The total dollar response for a situation without GxE interaction was predicted at $8.03. At \( k = 0 \), which represents the correlations calculated from the real data set, the total dollar response was $3.77. This is a 51% reduction in total dollar response compared to a situation without GxE interaction.
Figure 1. Genetic correlations for CFW (♦), FD (■), BWT (▲), CVFD (●) and SS (✖) in different environments as a function of the parameter k.

Figure 2. Total dollar response (-----) and trait dollar response per year through selection index for cCFW (◆), cFD (■), cBWT (▲) and cSS (✖) in dollars as a factor of different effects of GxE interaction (k).

The minimum dollar response per year observed was $2.14 at k = -0.5. The highest total dollar response of $11.18 was achieved at k = -1 a situation with extreme GxE interaction. This latter result involved inconsistent G-matrices, which led to the higher predicted dollar response at k = -1 than at k
cFD and cCFW were the traits with highest economic importance. They contributed most to the reduction in dollar response at k = -0.5 compared to k = 1, whereas for cBWT and cSS the predicted dollar response was low across all values of k. At the point of minimal response total dollar response was around 70% of that of a situation without GxE interactions.

Of most interest was the predicted dollar response at k = 0 because the genetic correlations relate to a real situation represented by the Wool Tenderness data set. The correlations ranged between 0.50 and 0.76 at k = 0. The predicted reduction in genetic gain for cCFW and cFD and mild increase for cBWT and cSS resulted in a considerable reduction in total dollar response of 51% compared to no GxE interaction (k = 1). This shows that under the most optimal scenario, with known genetic parameters, GxE interactions between management systems in the same Western Australian climate can have a considerable effect on predicted dollar response for commercial producers.

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REFERENCES