A METHOD TO ESTIMATE ECONOMIC WEIGHTS FOR TRAITS OF DISEASE RESISTANCE IN SHEEP

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SUMMARY

Estimating relative economic weights for disease resistance is difficult because disease has multifold influences on costs and revenue and is further complicated by environmental factors, nonlinearity effects and interactions. An objective method is described where, for a given set of assumptions, breeding objectives are matched to expected responses in traits and production trait responses are maximised relative to overall gains. In a two trait index of body weight and faecal egg count (h^2 = 0.4 and 0.3 and phenotypic variances = 20.5 kg^2 and 4(x1000) epg^2 respectively; genetic and phenotypic correlations of 0.3 and 0.01 respectively), the economic weight of the latter trait relative to body weight is -0.85 if the objective is to maximise the value of production relative to overall gains. Other objectives and relative economic weights for faecal egg counts were also estimated.

INTRODUCTION

Estimates of heritability for some disease resistance traits (Piper, 1987, Woolaston *et al.*, 1991, Raadsma 1991, Baker *et al.*, 1990, Towers *et al.* 1990) range between low to medium, suggesting that resistance to these diseases has some genetic basis. In the many environments where economic benefits can be achieved by selecting for disease resistance (Ponzoni, 1984, Piper and Barger, 1988), disease resistance is a significant component of the breeding objective.

Profit equations are often used in animal breeding to calculate economic weights for performance traits that comprise the breeding objective. In contrast, resistance has multifold influences on input and output which in turn affect profit. Resistance reduces the risk of infection and consequently the costs associated with disease control and it allows full expression of genetic potential. Three major characteristics make it difficult to incorporate measures of disease resistance into a profit equation. Firstly, the incidence, severity and therefore cost of disease control vary due to a large number of factors including nutrition, management, climate, production level, physiological stress and their interactions. Secondly, the economic advantage of resistance is multifold and cannot be easily accounted for. Advantages include savings from the use of chemicals (pesticides, antibiotics, vaccines and associated costs) and their residues in products and the environment, changes in management strategies to enable control, loss of production due to disease, replacement of diseased animals and risk of pathogen adaptation to chemicals agents. Thirdly, estimates of production loss per unit pathogen will be arbitrary because they will differ over time or between locations, there will be nonlinearity associated with severity of infection and also interaction between these factors.

Methods such as the restricted index (Kempthorne and Nordskog, 1959; Tallis, 1962) have been proposed but these methods have weaknesses and are arbitrary (Malard, 1972). A desired gains approach was developed by Pesek and Baker (1969) where expected gains were again arbitrarily chosen by the breeder before index weights are calculated. This paper outlines an approach to estimate the relative economic weight of disease resistance traits, based on known genetic and phenotypic parameters of the traits of the index, and objectively optimising gains on production traits.

SELECTION INDEX THEORY

Hazel's (1944) vector of selection index weights is

$$\underline{b} = \mathbf{P}^{-1}\mathbf{G}\underline{a} \qquad (1)$$

where $\underline{b}$ is a vector of index weights such that the true merit of the traits in the breeding objective are maximised. The dimension of $\underline{b}$ is c x 1 where c is the number of selection criteria traits. **P** is the c x c matrix of phenotypic (co)variances of selection criteria traits. **G** which has dimension c x p, is the genetic (co)variance matrix of traits selected and traits in the breeding objective, p the number of traits in the breeding objective. $\underline{a}$ is a vector of economic weights (in dollars) of traits in the breeding objectives of dimension p x 1. The response (in trait units) to selection per generation for each trait is given by the c elements of the vector $\underline{R}_u$ where

$$\underline{R}_u = \quad \underline{b}'\mathbf{G}/\sigma_I \; * \, i \qquad (2)$$

where σ_I is the standard deviation of the index and i the selection intensity assumed to be 1 throughout this paper. Assuming the objective function is expressed in dollar units, then response in each trait is

$$\underline{R}_\$ = \quad \underline{b}'\mathbf{GL}/\sigma_I \; * \, i \qquad (3)$$

where **L** is a matrix of economic weights on the diagonal with zeros on the off diagonals. The overall response is the sum of all the elements of $\underline{R}_\$$ and can also be expressed as $i\sqrt{(\underline{b}'\mathbf{P}\underline{b})}$.

ESTIMATION OF ECONOMIC WEIGHTS

The approach is demonstrated by way of an example with two traits where animals are selected for body weight (in kg, trait 1) and against faecal egg count (x 1000 eggs per gram, trait 2). It is assumed that the heritabilities are 0.4 and 0.3 and phenotypic variances 20.5 kg^2 and 4 $(x1000\ epg)^2$ respectively (Sivarajasingam, 1995), with genetic correlation 0.3 and phenotypic correlation 0.01. an economic weight for body weight (a_1) could be estimated readily from profit equations but is taken to be 1, and the economic weight for resistance, a_2 (or susceptibility, $-a_2$) is estimated relative to that of body weight.

<u>Selection responses</u>

Response in traits 1 and 2 are calculated for a range of values of a_2, and presented graphically in Figures 1 and 2. The responses (from equation 2) in Figure 1 are in trait units and in Figure 2 (from equation 3) are in \$ value. As values of a_2 decreased from 3 to -6, response in trait 1 increased, reached a maximum and then decreased. The same responses were observed for the traits in both figures because a_1 was assumed to be 1; the trend will be the same for other values of *i*. The maximum was at $a_2 = 0$, i.e. no emphasis was placed on epg, but this trait gave additional information on the animals. As expected epg response decreased (Figure 1) as emphasis on this trait was decreased and then selected against. Zero response was reached when a_2 was -1.60. When expressed in dollar value, response in this trait assumes a parabolic shape. Both figures also show the overall response curve (same as standard deviation since selection intensity is assumed to be 1).

<u>Economic weight - desirable range</u>

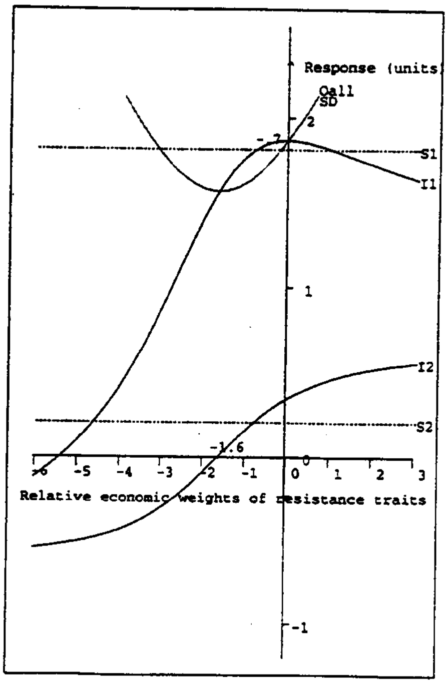
Figures 1 and 2 provide clues for an appropriate economic weighting factor for disease resistance trait if the desired responses are objectively defined. The general objective is to improve trait 1 and minimise positive response in trait 2, so large positive values of a_2 are detrimental. The highest a_2 value in the range could be the point when the value of response in trait 1 at least equals the overall response. These curves intersect at two points, so the right-most of these is the upper limit of a_2. Response values to the left of this point levels and then decrease for trait 1 and decrease in trait 2. The points of intersection for the above genetic [redacted]

The lower limit of this range could be the left intersection of trait 1 and overall response curves. However this point coincides with the point when response in trait 2 equals zero and there are situations when the breeder wants to reduce level of trait 2 rather than keeping it constant. The consequence of lowering a2 below -1.60 has a desired response in faecal egg count but there will be also a drop in trait 1 response especially when genetic correlations are positive. An examination of the rate of reduction in response in each trait could be used to minimise losses in trait 1. Marginal values for the responses $\underline{R}_u$ could be calculated by taking the first derivative of equation 1 with respect to a2 which is

$$\frac{\underline{e}_2' \mathbf{A}}{\sqrt{(\underline{a}' \mathbf{A}\, \underline{a})}} - \frac{\underline{e}_2' (\mathbf{A}+\mathbf{A}')\, \mathbf{a}}{2(\underline{a}' \mathbf{A}\, \underline{a})^{3/2}} \; \underline{a}'\mathbf{A} \qquad (4)$$

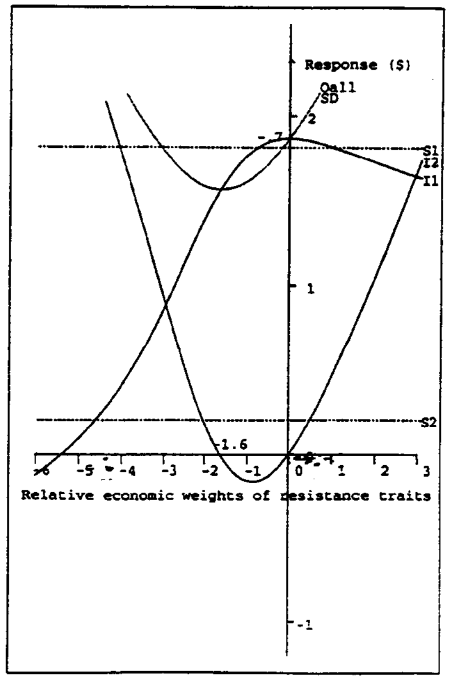
where $\underline{e}_2'$ = (0 1) and A = $GP^{-1}G$. When marginal responses for traits 1 and 2 were maximum, a_2 was -2.55 and -1.60 respectively. These are also points of inflection for each of the curves. Lowering a_2 from -2.55 will reduce response in trait 1 at an increasing rate but the decline in the rate of decline in trait 1 response is small. Therefore the lower limit of the range will be the point of inflection in trait response curve, i.e. -2.55.

Figure 1. Response curves in trait units over a range of trait 2 economic weights



S1 = single trait selection respcr.se for trait 1
S2 = correlated response in trait 2 for single trait selection on trait 1.

Figure 2. Response curves in dollars over a range of trait 2 economic weights



I1 and I2 = Index response in traits 1 and 2.
SD = standard deviation of index.
Oall = overall index response.

Economic weight within the range

Any a_2 value within the desirable range could be used, depending on the breeding objectives. The following are some of these breeding objective options:

1. When index response in trait 1 equals response from single trait selection (RI1 = RS1). Response in trait 1 is expected to be no worse than if faecal egg count is not measured.
2. When index response in trait 1 is maximum (RI1 = max). No compromise on trait 1 is allowed irrespective of the response in trait 2 which is included in the index.
3. When level of trait 2 is held constant (RI2 = 0).
4. When the mean value of trait 2 is lowered (RI2 < 0). A predetermined response of -0.2 (x 1000) epg is assumed.
5. When the mean value of trait 2 is lowered (RI2 < 0). A predetermined response of -0.3 (x 1000) epg is assumed.
6. When dollar value of trait 2 response is minimum ($RI2 = min).

All of the above options are valid under different circumstances. Often the criterion for the best index is highest overall index response. However this is not true when one of the trait in the index need to be selected against and normally handled by known economic weights. Figure 2 shows increases in overall index response after trait 2 reached zero response. This increase in overall response is only due to the double negative values of a2 and trait 2 response as shown by the increasing trait 2 response curve. Perhaps a more appropriate *criterion* is the proportion of overall response that is due to the production trait. The criterion that determines the best a2 is defined here as the dollar response achieved in trait 1 as a proportion of the overall response and is denoted as $\underline{Z}$.

$$Z = (\underline{R}_{\$} / \sqrt{(\underline{b}'P\underline{b})}) \times \underline{e}_1 \qquad (5)$$

where $\underline{e}_1' = (1\ 0)$. Table 1 compares the six options in terms of the relative economic weights a2 for each option and the corresponding responses in each trait, Z value, index standard deviation and correlation between index and true merit (r_{ti}).

Highest value of Z was obtained when value of faecal egg count reached its minimum as shown in Figure 2 and this was followed by option 1 when index selection and single trait selection on trait 1 were comparable for this trait. Except in option 3, although the overall response values were greater than that in option 6, the largest proportion of the advantage in the overall response is derived from gains in trait 1 in option 6 compared to all other options. Highest r_{ti} was when trait 1 response peaked (a2 = 0).

Table 1. Comparisons of various options for trait 2 economic weight.

	Options	a2 ($)	Z (%)	RI1 (kg)	RI2 (epg)	RIO ($)	rti
1	RI1 = RS1	-0.75	109	1.81	0.21	1.66	0.61
2	RI1 = max	0.00	100	1.87	0.35	1.87	0.65
3	RI2 = 0	-1.60	100	1.57	0.00	1.56	0.54
4	RI2 < 0 (= -.20)	-2.43	70	1.16	-0.20	1.65	0.50
5	RI2 < 0 (= -.30)	-2.94	50	0.89	-0.30	1.77	0.49
6	$RI2 = min	-0.85	110	1.79	0.19	1.63	0.60

a1 and a2 = economic weight for trait 1 and 2. Z = criterion.
RI1 and RI2 = Index response in trait 1 and 2. $RI2 = Index response in trait 2 in dollar value.
RIO = Value of index response in trait 1 and 2. SD = Index standard deviation
rti = Correlation between index and true merit. Responses in trait 2 given in epg x1000.
Single trait 1 response = 1.81 kg and correlated response in trait 2 = .208 epg.

DISCUSSION

Where breeding for disease resistance is practiced, the common breeding objective is to maximise returns from production and minimise costs of disease control. Depending on the disease prevalence, three approaches could be taken. Firstly, a large and negative economic weight for resistance could be chosen to reduce the disease incidence. Of the several options where a2 is less than -1.60 in the present study (e.g. options 4 and 5 above), points greater than -2.55 will be more desirable. For values less than this, the marginal decrease in response in trait 1 is larger than for the same unit of change in the x-axis for values greater than -2.55. Trait 2 response (Figure 1) also shows that the negative response plateaus for values of a2 less than -1.60. Therefore for the present case, a2=-2.55 so as to minimise marginal loss in trait 1 and achieve a negative response in faecal egg counts. In the second approach, the level of resistance is tolerable but the breeder does noy want any increase in susceptibility. The response in faecal egg count should therefore be zero and for the present example, a2 =-1.60; bearing in mind, because of the positive correlations, response in the production trait will also suffer. In the third approach, the primary concern of the breeder is to maximise returns and disease control procedures are able to handle marginally positive responses. In this approach, the breeder could choose a point when index trait response and single trait response are comparable (Sivarajasingam, 1995). However a better approach to estimate a2 could be to maximise the function where response in production trait is expressed as a proportion of the overall response. This could be calculated by setting the first derivative of Z with respect to a2, to zero and solve for a2. The value of -0.85 in the present study gave the highest response in production trait relative to overall response. If disease is not a serious threat, then other scenarios could be considered such as where a2 = 0 which will be the most desirable. The same principles could be extended to other situations where correlations differ and more than one production characteristic is included in the index.

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