# Genetics of adaptive traits

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## Summary

A focus on the genetics of adaptation in cattle is regaining importance primarily because of the need to produce consistent beef eating quality, which is often easiest to deliver from cattle breeds that are poorly adapted to tropical environments. Tick counts, worm egg counts, rectal temperatures, coat colour and coat scores have been studied as indicator traits of tropical adaptation. However, these traits are difficult to measure and poorly understood at a genetic level. Projects conducted through the Cooperative Research Centre for Cattle and Beef Quality (Beef CRC) recorded these adaptive traits in two distinct tropical breeds managed at several different northern Australian sites with varying levels of stressors typical of tropical environments. Genetic analyses of the data are underway at molecular and quantitative genetic levels. This paper presents preliminary results on the heritability of various adaptive traits and discusses possible relationships between them.

## Introduction

Tropical adaptation can be defined as an animal's ability to survive, grow and reproduce in the presence of endemic stressors of tropical environments (e.g. parasites, diseases, hot climates, poor seasonal nutrition). The economic implications for production systems due to the lack of adaptation include production losses, mortalities, treatment costs (where treatment is feasible) and marketing issues, for example associated with the presence of chemical residues in beef resulting from treatments to control parasites. The Beef CRC has investigated several of these adaptive traits in tropical beef cattle in northern Australia.

## Adaptive Traits

The cattle tick, Boophilus microplus, is a single host tick of Asian origin prevalent in tropical climates worldwide. Ticks not only reduce growth and reproduction, but they harbour disease agents, transmitting Babesia bovis, B. bigemina and Anaplasma marginale. To manage ticks, cattle producers use resistant breeds (Bos indicus) or crossbreds (B.indicus x B.taurus) or, where feasible, undertake acaricide treatments. In Australia, ticks are distributed around the northern coastal areas as far south as the Queensland – NSW border, where they are contained by a quarantine boundary at a cost of >A$7 million p.a. (White et al., 2003). Haematobia irritans, known as buffalo fly in Australia and horn fly in north and south America, is another important tropical ectoparasite affecting beef production. Resistance to ectoparasites is generally measured as the number of ticks (Wharton et al., 1970) or flies (Bean et al., 1987) on one side of the animal as a result of natural infestation. Buffalo fly lesion scores, recorded on a 1-10 scale, have also been used to measure resistance to buffalo fly infestation. The number of worm eggs per gram of faeces (Roberts and O'Sullivan, 1950) is used as a measure of resistance to endoparasites (gastro-intestinal helminths or worms, predominantly Haemonchus, Cooperia and Oesophagostomum spp.). The impact of parasite-borne tropical diseases is measured by the incidence and intensity of a wide range of diseases such as ephemeral fever (Australia) and trypanosomiasis (Africa).

Thermoregulation is a crucial factor for survival and production of cattle in tropical climates. Manifestations of effective thermoregulation include sleek coat, high sweating capacity and reduced metabolic heat production. Zebu cattle are well known for these attributes. Coat scores recorded on a 1 (extremely short and sleek coat) to 7 (very woolly coat) scale (Turner and Schleger, 1960) and rectal temperatures recorded under conditions of heat stress are used as measures of heat tolerance in cattle.

## Genetic parameters

The moderate to high heritabilities of adaptive traits from earlier northern Australian studies (Table 1) indicate these traits have a strong genetic component, providing ample scope for selection to improve them. However, they are difficult to include in genetic evaluation systems because of the difficulty of measurement.

**Table 1. Estimates of heritabilities of various tropical adaptive traits [A]**

| Reference | Location | Breed | Trait | $h^2$ (s.e.) |
|---|---|---|---|---|
| *Resistance to ticks* | | | | |
| Burrow (2001) | Australia | AX, AXBX | Count | 0.44 |
| Henshall *et al.* (2001) | Australia | AX, AXBX | Count | 0.42 |
| Henshall (2004) | Australia | HS | Count | 0.44 |
| Prayaga & Henshall (2005) | Australia | Crossbred | Count | 0.13 (0.03) |
| *Resistance to worms* | | | | |
| Burrow (2001) | Australia | AX, AXBX | FEC | 0.35 |
| Henshall *et al.* (2001) | Australia | AX, AXBX | FEC | 0.57 |
| Henshall (2004) | Australia | HS | FEC | 0.41 |
| Prayaga & Henshall (2005) | Australia | Crossbred | FEC | 0.24 (0.03) |
| *Resistance to buffalo flies* | | | | |
| Burrow (2001) | Australia | AX, AXBX | Count | 0.36 |
| *Resistance to heat stress (rectal temperature)* | | | | |
| Burrow (2001) | Australia | AX, AXBX | $^0$C | 0.17 |
| Prayaga & Henshall (2005) | Australia | Crossbred | $^0$C | 0.12 (0.03) |
| *Resistance to heat stress (coat score)* | | | | |
| Prayaga & Henshall (2005) | Australia | Crossbred | Score | 0.26 (0.03) |

[A]HS–$F_{5+}$ Hereford-Shorthorn *(Bos taurus)* cross; BX-$F_{5+}$ Brahman *(Bos indicus)* x HS; AX- $F_{5+}$ Africander *(Sanga, a tropically adapted taurine breed)* x HS; $F_{3+}$ AXBX, a cross of AX and BX; $h^2$ - heritability; s.e. – standard error; FEC - faecal egg count

Moderate favourable genetic correlations have been reported between resistance to ticks and worms (0.21 to 0.30) and ticks and heat (0.22 to 0.31; Burrow, 2001; Prayaga and Henshall, 2005). The latter also reported a moderate (0.17) genetic correlation between resistance to worms and heat, suggesting resistance to parasites and heat. Hence, selection to improve performance in any adaptive attribute may have favourable correlated responses that increase performance in other adaptive traits. Reports on genetic relationships between resistance to parasites and growth traits vary. While low and positive (unfavourable) genetic correlations were reported between resistance to ticks and worms and postweaning growth traits by Prayaga and Henshall (2005), moderate and negative genetic correlations (favourable) were reported by Burrow (2001). Based on a review of the literature, Davis (1993) also reported variable estimates and suggested this may be due to the different breeds in the various studies. Mackinnon et al. (1991) and Burrow (2001) reported positive (unfavourable) genetic correlations between body weights and fly counts leading to suggestions that higher testosterone levels or other metabolic products in heavier animals attract buffalo flies. An alternative explanation could simply be that larger skin surface areas in heavier animals allow an increased number of flies. However, the reported lack of relationship between buffalo flies and growth traits leads us to believe that flies pose a greater animal welfare and hide damage problem, rather than a production problem, at least from a northern Australian perspective.

Genetic correlations between resistance to heat stress and growth traits are generally significantly negative (favourable) across several studies cited above, emphasising the close relationship between genes controlling growth in the tropics and rectal temperatures. Genetic correlations between growth traits and coat scores were favourable but lower than those between growth and rectal temperatures (Prayaga and Henshall, 2005), indicating the complexity of thermoregulation with components such as sweating, respiratory cooling and lower metabolic heat production contributing to this trait (Turner, 1984). Favourable genetic correlations were reported between resistance to heat and measures of female fertility (Turner, 1982; Burrow, 2001). However, more research is required to understand female fertility in the tropics in general, and its relationship with adaptation, in particular. Current research programmes undertaken by the Cooperative Research Centre for Beef Genetic Technologies (Beef CRC) are addressing these issues in Australia.

## Breed differences

Cattle breeds differ in their ability to tolerate stressors such as parasites and heat. Hence, it makes sense to use breeds that are best suited to the tropics, not only to increase efficiency of production in these climates, but also to decrease the reliance on chemicals to combat parasites and tropical diseases. However, Zebu breeds that are highly resistant to parasites and heat (e.g. Utech et al., 1978; Frisch and Vercoe, 1984; Frisch et al., 2000) have lower reproductive rates and poorer meat quality attributes than Bos taurus breeds that are less well adapted to stressors of tropical areas. Because of the advantages to be gained through heterosis and breed complementarity among Bos indicus and Bos taurus breeds, crossbreeding is an efficient breeding tool in tropical beef enterprises and is gaining importance in tropical regions of Australia. Prayaga (2003) reported significant negative (favourable) heterosis percentages for tick counts (-40), faecal egg counts (-20), rectal temperatures (-0.32) and coat scores (-12) in crosses between Zebu and tropically adapted British breeds. Significant (P<0.01) genotype differences were also evident, with Zebu and Zebu crosses performing better than taurine crosses. Significant maternal breed additive effects for faecal egg counts, rectal temperatures and coat scores were also reported (Prayaga, 2003), with Zebu dam breeds contributing negatively (favourably) to this effect. Direct dominance effects between taurine – indicine crosses were negative (favourable) and significant for all adaptive traits, indicating a genetic basis for heterosis. Significantly lower rectal temperatures (Turner, 1982) and sleeker coats (Turner and Schleger, 1960) were reported in Zebu crosses cf. British breeds, indicating Bos indicus animals have better thermoregulatory capabilities.

## Beef CRC Project

The Beef CRC has undertaken a project to increase the knowledge of genetic relationships between components of herd profitability in northern Australian environments, to improve efficiency and product quality without compromising breeder herd performance and adaptability. A detailed description of the experimental design and animals and the traits recorded are given in previous publications (Burrow et al. 2003; Burrow and Bindon, 2005). In brief, the breeding program comprised of 2 tropically adapted breeds i.e. Brahmans and tropically adapted composites. Around 2400 progeny per breed were produced on 11 properties in Queensland and Northern Territory at the rate of 20 – 30 progeny for each of the 40 – 50 sires. Details of the sire selections are outlined in the earlier publications. Genetic linkages were generated among various management groups to the extent possible using artificial insemination. Steer progeny were allocated to one of the 5 growout properties in Central Queensland and NSW and heifer progeny were reared under a range of extensive environments at 4 research stations in Queensland (Toorak, Julia Creek; Swans Lagoon, Ayr; Belmont, Rockhampton; and Brian Pastures, Gyandah). During the growout phase, steers were measured for growth and adaptive traits. Heifers were measured for traits associated with growth, puberty and adaptive traits during their growing phase.

## Traits Recorded

A description of the range of adaptive traits recorded on Beef CRC heifers and steers are presented in the Table 2.

## Data analyses

Genetic analyses were conducted for heifers and steers separately. Data editing, in general, involved eliminating records with a) no date of birth information; b) data from sires with less than 3 progeny; and c) no information on sire breed or dam breed group. Contemporary groups with less than 2 sires or with an average number of progeny per sire fewer than 2 were deleted from the analyses. Fixed effects included contemporary group, sire breed group, dam breed group, dam year of birth, date of measurement and age at the time of recording and other interactions where significant. Contemporary group included geographic location, year of branding, season of birth and origin of the animal. Analyses were conducted using univariate animal models with ASREML (Gilmour et al. 2002).

## Preliminary results from the genetic analysis of adaptive traits

Summary statistics of adaptive traits recorded and the preliminary heritability estimates of these traits derived from Beef CRC datasets are presented in Tables 3 and 4.

The preliminary genetic parameter estimates derived from Beef CRC datasets are comparable to those derived from earlier literature estimates. Further analyses to estimate the more important genetic correlations between productive and adaptive traits (particularly feed efficiency and carcase and beef quality in steers and reproductive performance in heifers) are underway.

**Table 2. Abbreviations and definitions of traits involved in the study**

| Trait | Definition |
|---|---|
| TICK | Log transformed tick scores based on the number of ticks on one side of the animals, Scores: 0 for 0 ticks; 1 for 1- 10 ticks; 2 for 11- 30 ticks; 3 for 31- 80 ticks; 4 for 81- 150 ticks; 5 for 151+ ticks. |
| EPG | Cube root transformed number of worm eggs per gram of faeces |
| FLY | Log transformed bufflalo fly lesion scores recorded based on the intensity of lesions on a 1 to 5 scale with 1 - no lesions and 5 – extensive lesions |
| TEMP | Log transformed rectal temperatures of animals recorded during summer months when ambient temperatures were >30$^0$C |
| COAT | Coat score of animals recorded on a 1 to 7 scale, 1 – extremely short and sleek coat and 7 – very woolly coat. Each of these scores is subdivided into fractional scores e.g. 1 is subdivided as 1.0, 1.3 and 1.6, to account for sub-classes. For analysis purposes these were converted on to a continuous scale of 1 to 17. |

**Table 3. Summary statistics of various adaptive traits (after data editing)**

| Trait | No.of animals | No.of records | No.of sires | Average no.of progeny per sire | Mean* (s.d) | Range* |
|---|---|---|---|---|---|---|
| TICK | 909 | 1302 | 77 | 11.8 | 1.22 (1.24) | 0 to 5 |
| EPG (heifers) | 2070 | 4569 | 100 | 20.7 | 325.8 (378.2) | 0 to 4800 |
| EPG (steers) | 1567 | 3795 | 94 | 16.7 | 429.4 (569.5) | 0 to 8850 |
| FLY | 2008 | 4060 | 100 | 20.8 | 1.49 (0.77) | 1 to 5 |
| TEMP | 1074 | 1457 | 89 | 12.1 | 39.17 (0.59) | 37.1 to 41.2 |
| COAT (heifers) | 2072 | 5847 | 100 | 20.7 | 5.21 (3.13) | 1 to 17 |
| COAT (steers) | 1984 | 6338 | 95 | 20.9 | 5.72 (2.67) | 1 to 17 |

* means and ranges are based on the non-transformed data

**Table 4. Preliminary estimates of heritability for various adaptive traits**

| Trait | N | $h^2$±s.e. | $c^2$±s.e. |
|---|---|---|---|
| **1. Tick Scores (heifers only)** | | | |
| First counts | 909 | 0.19±0.09 | - |
| Repeated counts | 1303 | 0.14±0.07 | 0.01±0.07 |
| **2. Faecal egg counts** | | | |
| *Heifers* | | | |
| First counts | 2070 | 0.33±0.07 | - |
| Repeated counts | 4569 | 0.25±0.05 | 0.05±0.04 |
| *Steers* | | | |
| First counts | 1567 | 0.15±0.07 | - |
| Repeated counts | 3796 | 0.14±0.05 | 0.06±0.04 |
| **3. Buffalo fly lesion scores (heifers only)** | | | |
| First counts | 2008 | 0.17±0.05 | - |
| Repeated counts | 4060 | 0.17±0.05 | 0.32±0.05 |
| **4.Rectal Temperatures (heifers only)** | | | |
| First counts | 1074 | 0.26±0.10 | - |
| Repeated counts | 1457 | 0.13±0.06 | 0.06±0.07 |
| **5.Coat Scores** | | | |
| *Heifers* | | | |
| First counts | 2072 | 0.50±0.09 | - |
| Repeated counts | 5847 | 0.37±0.05 | 0.00±0.05 |
| *Steers* | | | |
| First counts | 1984 | 0.22±0.06 | - |
| Repeated counts | 6338 | 0.15±0.04 | 0.12±0.03 |

N – number of records; $h^2$ – heritability; $c^2$ – permanent environment due to animal; s.e. – standard error

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