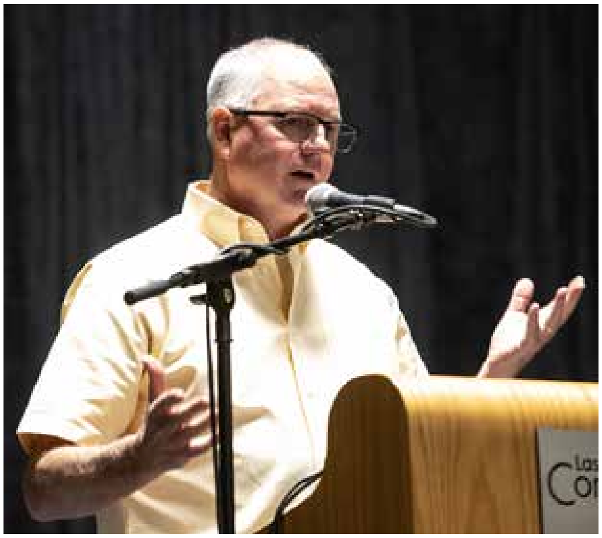
Harnessing Genetic x Environment (G x E) Interactions – are They Important in Production? — Milt Thomas



On Behalf of W1: Beef Cattle Breeding Group of the Agricultural Experiment Stations of the Western States of the U.S.

G x E and (or) fitting animals to the environment

Gene x environment interaction, often referred by the acronym G x E, means that there are animals that perform better in some environments than others; therefore, G x E is important to beef production. The graph below (Figure 1) is an historic example of G x E. These results are from a study conducted by the USDA Agriculture Research Service and experiment stations in Montana and Florida. In brief, Hereford herds were maintained at each location and some cattle at each location were moved to the other location. The results were that the cattle from Montana performed best in Montana and the cattle from Florida performed best in Florida.

A simple explanation of these results is somewhat like home field/court advantage in competitive sports. However, G x E is more than just the E and moving cattle to the other environment. As the ability to do genomic analysis was gained, scientific efforts revealed that there are concentrations of alleles in specific environments (Krehbiel et al, 2019; Rowan et al., 2021). Alleles are alternative forms of genes and recent research revealed that there are frequencies of alleles unique to environment(s), which is a result of breeders selecting cattle that are most suitable to that environment. Because of this knowledge, it encourages the scientific and breed association community to continue to advance research so that environmental adaptability can be determined early in the life of cattle. To most, discussion of G x E is much more about fitting the most appropriate cattle to the resources of a production system; therefore, the definition of G x E can be much more than about environmental adaptability, it can also be about the various types of production systems that can exist within an environment. Examples of such differences could be a cow/calf production system versus a vertically coordinated system that markets beef based through a direct market.

See Figure 1: Gene x environment interaction in Hereford cattle. In brief, cattle bred and residing in Montana had better weaning weight in Montana than the cattle bred to live in Florida and vice versa (Burns et al., 1979). Figure also published by Hammack (2009).

Environmental challenges and G x E

Even though it is challenging to gather the data needed to conduct statistical analyses to detect G x E, there are substantial environmental differences among beef production systems. Temperature, humidity, annual rainfall and drought, and altitude are obvious within these historic discussions as are conversations of which cattle best fit specific environments. In general, and for the U.S Beef Industry, Bos indicus-influenced (Brahman) cattle are most prevalent in hotter climates and Bos taurus cattle are most prevalent in cooler and colder climates.

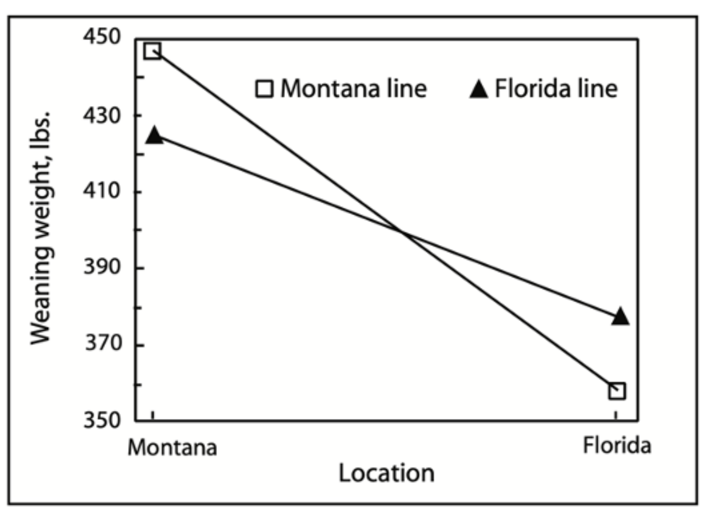
However, and more recently, impacts of climate change and sustainability have become part of the U.S. Beef Industry's strategic planning processes and goals. To be specific, climate neutrality is a goal stated by National Cattlemen's Beef Association and the US Roundtable for Sustainable Beef; therefore, future discussions and efforts to understand and take advantage of G x E as it relates to sustainability factors such as carbon footprint are expected; especially, since beef cattle are ruminants and breathe-out methane (Dillon et al., 2021).

Genetic challenges and G x E

Breeding objectives for beef cattle in the U.S. has changed many times throughout history. For example, belt buckle high (very short) cattle of the 1950s gave way to extremely tall (i.e., high frame score) cattle of the 1980s. More recently, the U.S. Beef Industry has been maintaining a consistent annual supply of beef with a smaller national cow herd because of the increased size (i.e., weight; USDA-NASS, 2022). Traits of size (i.e., yearling weight, mature weight, carcass weight) are of high heritability and the concept of a reduced national cow herd helps with the goal for moving towards a climate neutral industry.

However, in harsh environments and particularly across the Western U.S., traits more indicative of environmental adaptability may be of more importance within breeding objectives than increased size. Examples of environmental adaptability traits

Figure 1: Gene x environment interaction in Hereford cattle

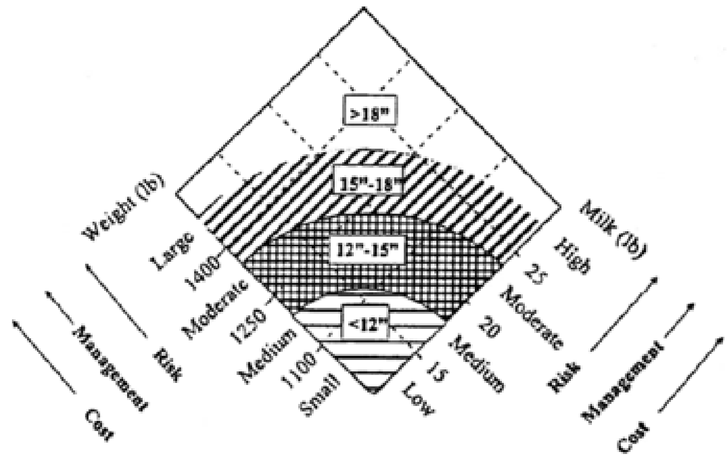


include, milk production, grazing distribution, temperature, and altitude tolerance, etc. Members of the Western U.S. Agricultural Experiment Stations (W1) considered adaptability of the cattle in numerous breeding projects. This consideration was also done with understanding of the importance of hybrid vigor from crossbreeding and (or) composite cattle. The following diagram (Figure 2) illustrates how cow weight and milk production should change with rainfall. Crossbreeding research using Hereford and Brangus cattle helped design this figure and revealed that hybrid vigor was very helpful for productivity in a desert beef production system (Winder et al., 1992).

See Figure 2: Matching cow biological type (weight and milk) to range environment, with associated risk, management, and cost. Ranges in inches (12”-15”) are annual precipitation and (or) represent availability of winter feed resources (W1, 1999).

Summary and conclusions: G x E exist in beef cattle. It is important to understand this interaction to select cattle that are adapted and fit specific environments and production systems. The ability to detect G x E has increased with genomic approaches and information from spatial databases providing opportunity to study and develop genetic improvement tools for adaptability.

Figure 2: Matching biological type (weight an milk) to range environment, with associated risk, management and cost



References:

Burns, W. C., M. Koger, W. T. Butts, O. F. Pahnish, and R. L. Blackwell. 1979. Genotype by environment interaction in Hereford cattle: II. Birth and weaning traits. J. Animal Sci. 49:403-409.

Dillon, J.A., K. R. Stackhouse-Lawson, G. J. Thoma, S. A. Gunter, C. A. Rotz, E. Kebreab, D. G. Riley, L. O. Tedeschi, J. Villalba, F. Mitloehner, A. N. Hristov, S. L. Archibeque, J. P. Ritten, and N. D. Mueller. 2021. Current state of enteric methane and the carbon footprint of beef and dairy cattle in the United States. Anim. Front. 11:57-68.

Hammack, S. P. 2009. Texas adapted genetic strategies for beef cattle II: genetic-environmental interaction. Tex. A&M AgriLife Extension E-187.

Krehbiel, B. C., M. G. Thomas, C. S. Wilson, S. E. Speidel, R. M. Enns, S. R. Paiva, and H. D. Blackburn. 2019. Evaluation of genetic structure across U.S. climate zones using prominent AI sire of Red Angus cattle. Livst. Sci. 225:26-31.

Rowan, T. N., H. J. Durbin, C. M. Seabury, R. D. Schnabel, and J. E. Decker. 2021. Powerful detection of polygenic selection and evidence of environmental adaptation in US beef cattle. PloS Genet. 16:e1009652.

Winder, J. A., B. J. Rankin, and C. C. Bailey. 1992. Maternal performance of Hereford, Brangus, and reciprocal crossbred cows under semidesert conditions. J. Anim. Sci. 70:1032-1038.

W1. 1999. Crossbred beef cattle for western range environments. 2nd ed. TB-99-1. For e-copy, contact: milt.thomas@colostate.edu or mark.enns@colostate.edu.