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INTERBREED EVALUATION OF BEEF CATTLE PRODUCTIVITY UNDER LOW AND MODERATE DRY MATTER AVAILABILITIES

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SUMMARY

Costs limit live animal experimentation to quantify genotype by environment interactions in herd productivity due to the number of production environments and beef cattle germ plasm combinations. Life cycle simulation models enable producers to evaluate breeds differing in genetic potential for productivity under a variety of environmental conditions; e.g., inter- or intra-breed by environment interactions. A simulation model developed for within ranch evaluations, DECI, was parameterized to evaluate~~d~~ productivity for a constant calving population inventory herd of two biological types of beef cattle across two production environments differing only in annual yields of dry matter (DM), low and moderate. The two biological types evaluated differed in genetic potentials for mature size and peak milk yield with each type having associated attributes; e.g., propensity to fatten, measures of fertility, dystocia and maintenance requirements. Ranking for weight of calf marketed per cow exposed of the two biological types differed depended on environment. Under restrictive DM the biological type with greater genetic potential for growth and milk production marketed fewer kilograms of product per cow exposed. At moderate DM availability, the biological type with greater genetic potential yielded more of this product. Application of dynamic simulation models provides an opportunity to investigate genotype by environment interactions.

INTRODUCTION

Hammond (1947) stated "… thus environmental condition existing at any given time will lead to the natural selection of genes giving rise to characters in harmony with the environment concerned." Failure to realize greatly increased levels of productivity when using animals with greater genetic potential is well documented (Lin and Togash 2002); this is due to emphasis on output rather on the "harmony" of the animal with the challenges to be encountered in the production environment. For beef cattle producers, environment is made up of all non-genetic factors; those normally considered include green grass days, temperature, humidity, parasites, etc., but factors not normally considered are the primary product and the marketing end points for the primary product. The challenge is to evaluate productivity of biological types with diverse genetic potentials for production across a wide range of environmental conditions. The present study applies a dynamic simulation model to characterize the productivity of two biological types differing in genetic production potentials interacting with differing feed environments.

MATERIALS AND METHODS

Model information. A dynamic, mechanistic life cycle herd level simulation model capable of tracking daily events for individual animals was parameterized to evaluate productivity of two biological types differing in genetic potentials in two nutritional environments. The Decision Evaluator for the Cattle Industry (DECI) is a herd inventory model incorporating mechanistic and empirical equations at the tissue level to predict cattle performance (Jenkins and Williams 1998; Williams *et al.* 2006). DECI was designed to allow producers to evaluate the impact of strategic management decisions on herd productivity over time, including the interaction of genetic potentials of cattle with various environmental conditions (management, nutritional, and market endpoint) and to identify constraints that limit full expression of genetic potential. Feed environments are defined by defining forage availability and quality, either grazed or harvested, and times of availability during the production year. Breed means derived from breed evaluations in the Germ Plasm Evaluation and Germ Plasm Utilization projects at MARC (Cundiff *et al*. 1998; Gregory *et al*. 1999) are used as the genetic potentials for 20 characters contributing to an animal's phenotypic performance. These potentials are stored in a data set accessible internal to the program. Mating systems provide the user with the ability to use heterosis and breed differences. Maximum cowherd size per simulation is 500 pregnant cows at the beginning of the inventory year.

Approach. Two production environments were parameterized to differ only in availability (pasture and harvested supplements) of dry matter (DM), all other environmental factors being held constant. Forage resources available to the animals were programmed to reflect a normal forage production year for expected forage protein and energy content based on dry matter yields. This approach allows seasonal variation in the two dry matter availability (indicator of energy intake) environments that were simulated: 4000 kg and 6700 kg per cow per year. Other management factors in common were simulated herd size (set at 150 pregnant females at the beginning of the inventory year), breeding seasons were 90 days using bull genetic potentials within biological type, simulated male calves were castrated soon after birth, calves did not receive supplemental feeds, and all calves were weaned on a single day. Two biological types differing in genetic potential, Moderate (M) and Greater (G) for weight and maturity and peak milk were identified (Table 1). For each type the simulation model was parameterized for all characters using the genetic potentials of breeds derived from the GPE and GPU (studies imbedded in a data base of DECI) associated with each type. Three 15 year simulations created a final herd of the correct genetic potential that was at a herd age equilibrium within each nutritional environment.

Table 1. Genetic potentials for two biological types of cattle

	Moderate	Greater
Potential		
Birth weight, kg	40	42
Mature weight, kg*	630	744
Peak milk yield, kg**	10.4	11.4

*at 26% body fat
**at time of peak lactation

RESULTS AND DISCUSSION

Predicted performance. Predicted values for traits of interest within each nutritional environment are reported in Table 2. Within the 4000 kg DM environment, predicted responses for cows 5 years or older of the two biological types are reported for weights and condition scores at time of calving, start of the breeding season, and weaning time. Under restricted DM availability, predicted body weights of M mature cows varied across the production year as demand for production energy changed. Response in condition scores (9-point system as an indicator of energy status at each of the three reporting times) suggests DM availability on average would have limited impact on expression of M genetic potential for productivity for either cows or calves in the herd. The G mature cows with greater genetic potential of mature weight and peak milk yield than the M, had predicted weights either less than or equal to those of the M. Low body condition scores suggest the probability of reproductive success for G females would be lower in the 4000 kg environment. For each herd, predicted mean postpartum interval of the M cows was 16 days shorter than that of G cows (68 d and 84 d; respectively) which could be attributed to negative energy balance of the G cows. With a restricted breeding season longer postpartum intervals contributes to lower pregnancy rates, so that predicted herd mean pregnancy rates were 86 and 74% for the M and G; respectively. To sustain a cow herd inventory of 150 pregnant females at the start of the inventory year, a mean of 182 females were exposed each year for the M herd in the 4000 kg environment compared to 200 females for the G herd. The difference in females exposed reflects a difference in the number of heifers that need to be retained to meet the requirement of 150 pregnant females at the start of the inventory year.

Table 2. Predicted performance of two biological types in two DM availability environments

	4000 kg annual DM		6700 kg annual DM	
	Moderate	Greater	Moderate	Greater
Mean 5-year-old cow				
Calving time wt, kg	555	509	647	684
Breeding time wt, kg	505	505	661	683
Weaning time wt, kg	522	483	627	635
*Mean 5-year-old cow CS**				
Calving time	5.5	2.8	7.0	5.8
Breeding time	4.5	2.6	7.1	5.8
Weaning time	4.8	2.5	6.6	5.0
Mean herd reproduction				
Postpartum interval, d	68	84	62	67
Number exposed	182	200	181	180
Pregnancy rate at weaning, %	86	74	93	94
Mean herd productivity				
Milk yield, kg/d	6.6	6.7	6.6	7.7
Number calves weaned	141	141	144	142
Weight/calf weaned, kg	195	224	212	253
Weight of calf marketed/ cow exposed	151	137	168	199

*CS condition score 9-point system 1 very thin – 9 very obese

With increased dry matter availability, both groups had higher predicted cow weights at each production segment and G cows with greater genetic potential were heavier than M cows although the M population continued to have higher CS. Both M and G exhibited improvement in reproduction and productivity traits in the better nutritional environment with the greatest improvement predicted for the G cows. Sufficient DM availability in the 6700 DM environment enabled the G genetic potentials for growth and milk production to be expressed and reproductive rate improved (fewer females exposed to maintain herd size) allowing 45% more weight of calf marketed per cow exposed. The M cattle had improved reproductive rates in the 6700 DM environment with slight improvement in predicted calf weight at weaning (17 kg) resulting in 11% improvement in weight of calf marketed per cow exposed.

Ranking of the M and G populations was dependent on the nutritional environment creating a biological type by environment interaction. Dry matter availability that varied across the production year was the constraining factor on herd productivity for the G population in the 4000kg DM environment with the availability during critical times of the year limiting the fertility and milk production of the cows and full expression of the growth potential of the calves. Maintaining a constant herd size of pregnant females required more replacement females to be retained in the breeding herd each year leading to reduced number of weaned calves for sale-reducing kg of calves marketed per female exposed. A CS of 2.6 for G population of mature females would have a smaller proportion of these females fertile during the restricted breeding season. Conversely, the M population's CS of 4.5 at the start of the breeding season indicate a higher probability for a greater proportion of the mature cows to cycle and conceive. Nutritional requirements more closely met the needs for expression of milk production in cows and for the growth potential of the calves, thus fewer replacement heifers were required to maintain herd inventory resulting in a higher yield of calf weight marketed per female exposed the previous breeding season. At increased DM availability (6700 kg), the rank of the two populations for this measure of efficiency changed. The reproduction rate of the G population increased by 20% resulting in an increase of 32 kg per female exposed (more heifers available for market). Sufficient body energy reserves and forage availability to not limit reproduction or the expression of genetic potential for milk production of the cow or the growth protential of the calves. The response in productivity at the 6700 kg of the M population was positive for reproduction and growth traits but to a lesser degree. The greater CS scores of mature cows at all times during the production year indictes cows were consuming energy in excess of their genetic potential for production. Even with unlimited energy availability in the 6700 kg environment, the M population average calf weight at weaning only increased 9% indicating limited genetic potential for growth of the calves.

CONCLUSIONS

Genotype by environment interactions affect herd productivity of cattle. Rank changes of importance are those that affect the relevant measure of productivity for a producer. The greatest impact of nutritional constraint in a cow herd is on the reproduction potential. For those interactions resulting from differing feed need attributable to greater genetic potential of one biological type relative to others, dynamic herd simulation models represents a tool to quantify the feed resources needed to benefit from the greater genetic potentials. With the diversity of genetic potential within and among cattle breeds, live animal experimentation is not feasible to investigate all potential genotype by environment interactions. Application of this tool expands the opportunity to evaluate the interactions for many breeds or breed crosses across a wide range of environmental conditions.

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