Utilization of linear prediction procedures to evaluate animal response to grazing systems

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Abstract

Best linear unbiased prediction (BLUP) procedures were used to separate genetic merit from environmental effects on 205-day weight (205-d wt) of calves produced by cows grazing 2 pasture systems. Phenotypic measures of 205-d wt were statistically partitioned into genetic effects (breeding value) and environmental effects. Means were regressed on year of birth of calf. Analysis of covariance was used to test difference in slope and elevation (means) of the regression lines. The continuously grazed pasture (CG) produced higher 205-d wt than did the rotationally grazed pastures (RG) ($P<.10$). Rate of change in 205-d wt was similar in the 2 grazing systems. Genetic merit was similar among the animals in the 2 grazing systems. The rate of change per year in genetic merit (genetic trend) was also similar. Means tended to vary sharply from year to year, indicating inequality of genetic merit should be taken into account in this type of data. Mean environmental effects resulted in greater ($P<.10$) 205-d weight in CG than in RG. Rate of change of environmental quality was similar in the 2 systems. These results indicate, from the animals perspective, the RG system did not improve productivity when compared to CG. The CG system was of higher nutritional quality, but the rate of change was similar to that of the RG system.

Key words: grazing systems, animal performance

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Grazing systems are usually developed for range improvement. In general, increased livestock or wildlife production are not major reasons for implementation (Pieper 1980). Effects of grazing systems on livestock performance are important considerations when economic feasibility of initiating a program is considered. The incentive to livestock producers to begin grazing management programs may result from potential increases, or at least a guarantee of maintenance, of animal performance while improving range quality.

Cow-calf production systems are the major users of the range resource in many areas of the United States. Thus, it is appropriate to evaluate grazing systems in these areas using cow-calf pairs as the mechanism for forage removal. Use of cow-calf pairs, however, creates potential problems in interpretation of experimental data. Generally, cows are randomly or uniformly assigned to pasture systems. This generally occurs at the onset of study. In this case, the researcher must assume genetic potential is equally distributed across pasture systems. He must also assume average genetic merit and genetic variation do not diverge over time. Both of these assumptions are probably invalid.

Mixed model prediction procedures have been developed to estimate the genetic merit of livestock. These procedures provide possible means to remove the biases caused by differences in genetic makeup of study animals.

The best linear unbiased prediction (BLUP) procedures described by Quaas and Pollack (1980) provide a mechanism to separate measurable phenotypic values of animals into 3 discrete causal categories. These are (1) the breeding value of the animal, (2) environmental effects, and (3) random error. The BLUP proce-

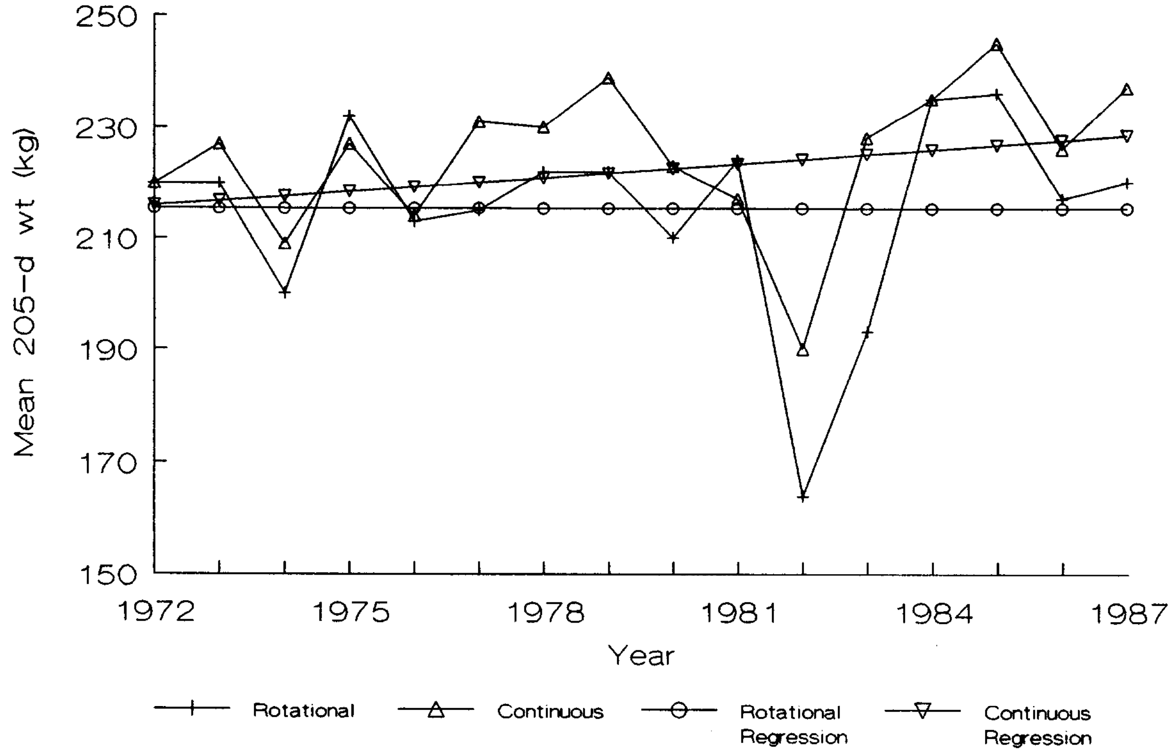

Fig. 1. Mean 205-d wt of Brangus heifer calves by year of birth in continuously and rotationally grazed pastures.

dures are most widely used to estimate the breeding values of individuals; the breeding value is the measure of an animal's value as a genetic parent. This can be thought of as the genetic merit that can be passed from parent to offspring. The ability to separate and measure certain environmental effects also has tremendous value as a research tool. Environmental effects can be isolated by designing management groups or contemporary groups. These groups are usually designated on the basis of sex, year, and management group. In this particular study, pasture system (rotational or continuous) was part of this contemporary group designation. This allowed measurement of the effects of these range management practices on the performance of grazing beef cattle.

The objectives of this study were (1) to evaluate potential basis in animal response data from grazing system reseach caused by different genetic potentials across treatment groups, and (2) to evaluate a mechanism for eliminating the potential bias.

Materials and Methods

Experimental Animals

The cattle involved in this study were purebred Brangus at the College Ranch operated by the New Mexico Agricultural Experiment Station. These data are based on measurement of preweaning growth of heifer progeny produced by cows grazing 2 pasture systems. Data on male calves are excluded during the study period because some males were castrated.

Two potential problems existed in the male calf data. First, all males were castrated in the early years of the study, but in the latter years, all males were left intact. Thus, neither intact male data nor castrate data spanned the entire study period. Second, if male data were pooled, the assumption would be that intact and castrated males respond equally to their environment. This assumption is probably flawed. In 1972, a Brangus herd was randomly assigned to 2 pasture management systems. One was a continuously grazed pasture (CG), the other was a system of 3 rotationally grazed pastures (RG). All replacement heifers were selected from within the overall herd. The heifers were then randomly assigned to grazing treatment. This process should have assured adequate genetic connectedness between grazing treatment groups. Preweaning growth measurements were made on progeny produced in the 2 grazing systems from 1972 through 1988. Weaning weights were adjusted to 205 days of age, in accordance with Beef Improvement Federation (1986) guidelines.

Study Area

The area is semidesert with an annual precipitation of approximately 225 mm. Common perennial grasses on these pastures are black grama *(Bouteloua eriopoda)*, dropseeds (*Sporobolus* spp.), and three-awns (*Aristida* spp.). There are many other perennial and annual grasses on the pastures. Mesquite *(Prosopis glandulosa)* is the most common shrub.

Stocking rates in the 2 pasture systems were maintained at similar levels throughout the study period. Average stocking rate was approximately .02 AUY per ha. The continuously grazed (CG) pasture was stocked without interruption from 1972 through 1988. Rotation of grazing in the RG system was based upon seasonal suitability, i.e., cattle were rotated to pastures on the basis of forage availability and season of the year.

Analyses

Adjusted 205-d weaning weights (205-d wt) were analyzed using the best linear unbiased prediction (BLUP) procedures in a single trait reduced animal model (RAM). These procedures were initially discussed by Henderson (1949) and have evolved with computer capability. Henderson and Quaas (1976) and Quaas and Pollock (1980) have described multiple trait models designed for the purpose of estimating genetic merit of livestock. The single trait model used in this study estimates genetic and environmental effects of each trait independently. This differs from a multiple trait model which utilizes relationships among traits as an additional means of predicting genetic values. The model for calculation is listed below in a matrix notation.

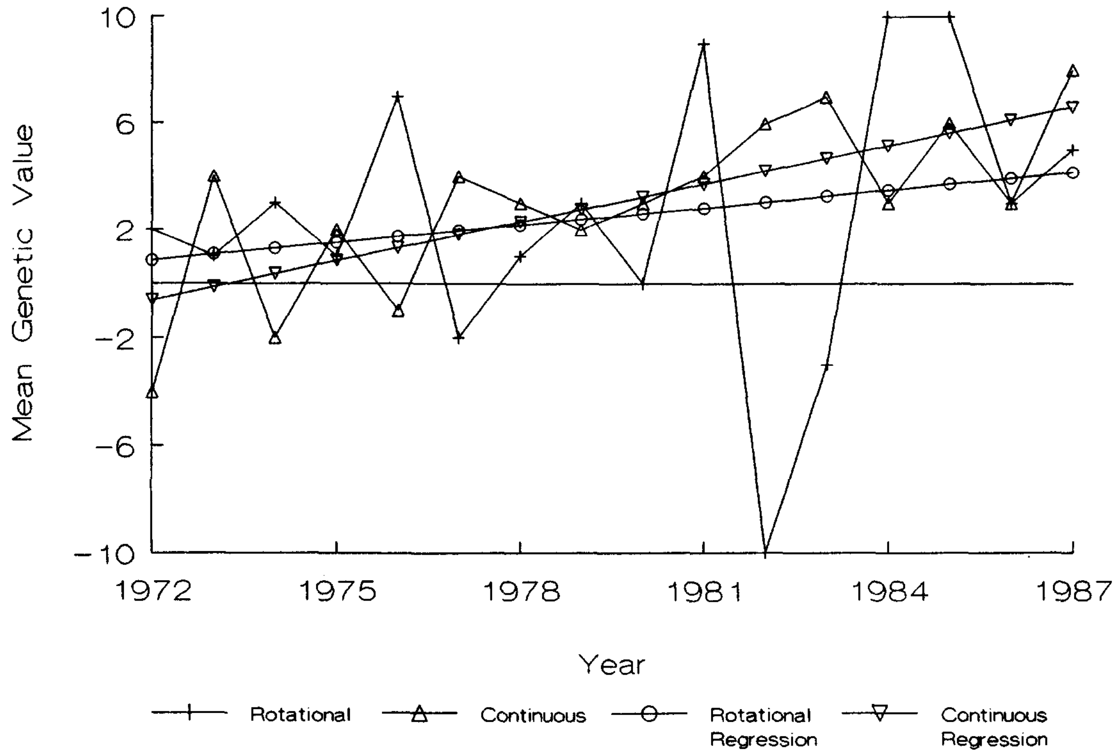

Fig. 2. Mean genetic value of Brangus heifer calves by year of birth in continuously and rotationally grazed pastures.

$$Y = XB + ZU + e$$

Where:
- Y = Vector of phenotypic performance records.
- B = Vector of fixed effects.
- X = Known incidence matrix relating performance records to fixed effects.
- U = Random effects vector representing direct breeding values or maternal breeding values.
- Z = Known incidence matrix for performance records to elements of U.
- e = Random vector, representing environmental peculiar to each performance record.

Contemporary groups were designated on the basis of sex of calf, year of birth of calf, and pasture systems. Estimates of population parameters are necessary to predict genetic and environmental values by this technique. These components were provided by the Department of Animal Science, the University of Georgia, Athens, and were derived from analysis of performance and pedigree data provided by the International Brangus Breeders Association, San Antonio, Texas. Estimated parameters were as follows: genetic variance for 205-d weight = 164 kg^2, additive maternal variance for 205-d weight = 116 kg^2 and environmental variance for 205-d weight = 322 kg^2. Year means for genetic values and environmental values were used to evaluate genetic and environmental trend, respectively. Genetic values are expressed in units of measure (kg) as a deviation from a population base. The population base is the average genetic value of those individuals without identifiable parents. Environmental values are least squares means generated by the BLUP procedures. These are independent of the effects of genetic values. In this study, these are least squares means for sex × year × pasture system subgroups.

Trend Analyses

Phenotypic, genetic, and environmental trends were evaluated both graphically and by analysis of covariance techniques. Phenotypic trend was defined as the change in 205-d wt per year.

Genetic trend was evaluated graphically by plotting mean genetic values on year of birth. This allowed gross evaluation of change in genetic merit over time. The designation of contemporary group by sex, year of birth, and pasture system allowed a similar evaluation of environmental trend. Graphic representation of environmental trend was accomplished by plotting mean environmental values for heifers on year of birth. Separate plotting of environmental values associated with each pasture system permitted comparison of environmental trend of the 2 grazing systems.

Mean 205-d wt, genetic values, and environmental values were regressed on year of birth. Differences in slope (regression coefficients) and elevation of fitted lines between pasture treatment groups were tested using analysis of covariance techniques described by Snedecor and Cochran (1978).

Results and Discussion

Results will be discussed in 3 sections. The first of these will include an analysis of phenotypic trend by pasture system. This might be thought of as a more traditional approach to examining the effects of grazing system on the animal component. The second section will examine a possible bias in the evaluation of phenotypic values. Bias is caused by change in the average genetic merit of the animals allocated to each grazing system. In this experiment, single sire mating schemes were used within grazing system. It is doubtful the rate of change in genetic merit would be parallel in the 2 herds. The third section will analyze the effect of environmental factors on the performance of the 2 herds. The environmental trend should provide the best estimate of the effect of the grazing system on animal performance.

Phenotypic Trend

Mean 205-d weights are listed by year and pasture system in Table 1. Year means are considered to be individual observations in terms of phenotypic trend analyses. The means of these observations were 217.2 ± 4.3 kg and 224.9 ± 3.2 kg for the rotational and continuous systems, respectively. The regression of mean phenotypic values on year of birth is presented in Figure 1. Average 205-d weights changed at an average annual rate of −.02 ± 1.0 and .81 ± .71 kg per year in the rotationally and continuously grazed systems,

Table 1. Distribution of heifers, mean 205-d weights, mean genetic values and mean environmental values by year of birth and pasture system.

Year of birth	Number of heifers weaned		Mean 205 d wt.[a]		Mean genetic value		Mean environ. value[a]	
	RG[b]	CG[c]	RG[b]	CG[c]	RG[b]	CG[c]	RG[b]	CG[c]
1972	3	4	220	220	1.9	−3.9	221	220
1973	12	5	220	227	.6	3.6	223	226
1974	12	9	200	209	3.1	−1.8	199	213
1975	9	9	232	227	.7	2.3	210	230
1976	7	12	213	214	7.0	−.8	212	217
1977	9	8	215	231	−2.0	3.6	217	226
1978	12	16	222	230	.9	3.0	223	230
1979	11	8	222	239	3.1	1.8	223	240
1980	13	13	210	223	0.0	2.7	210	222
1981	16	7	224	217	9.3	4.4	214	213
1982	15	8	164	190	−9.7	5.8	170	180
1983	10	10	193	228	−3.2	7.0	194	215
1984	10	5	235	235	9.6	2.7	225	235
1985	9	16	236	245	10.3	5.9	226	241
1986	12	12	217	226	3.5	2.6	213	224
1987	13	18	220	237	4.6	8.2	216	234
Means[d]	10.8	10.0	217.2	224.9	2.5	3.0	224.9	223.0
S.E.[e]			4.3	3.2	1.3	.8	3.5	3.5

[a]Kg.
[b]Rotationally grazed system.
[c]Continuously grazed system.
[d]Means of year means.
[e]Standard error of the mean.

respectively (Table 2). Results of analysis of covariance are listed in Table 2. Rate of change 205-d weights did not significantly differ in the 2 pasture systems. However, the continuously grazed system was more productive ($P<.10$) than the rotationally grazed system. This indicates either pasture conditions or genetic merit of study animals may be superior in the continuously grazed system. Because rate of change was determined to be nonsignificant ($P>.25$), this indicates a possible sampling bias at the beginning of experimentation.

Genetic Trend

A possible bias may be introduced in this type of data by change in genetic merit over time. Animals were randomly assigned to treatment group at the onset of the experiment (1972), but this does not assure constant genetic potentials over time. Average values for heifer calves reared in each pasture system are listed by year of birth in Table 1. Genetic trend is plotted as is the regression of mean genetic values on year of birth (Fig. 2). Mean breeding values increased at a rate of .22 ± .28 and .48 ± .12 kg per year in the rotational and continuous grazed systems, respectively. Although this is a potential error in the evaluation of animal response, analysis of covariance (Table 2) indicates genetic trend (rate of change in mean genetic values) did not differ ($P>.25$) between animals by grazing system. The elevation of the regression lines was also similar ($P>.25$). These results indicate average genetic merit and average change in genetic merit were similar in both pasture systems. It should be noted, genetic merit was quite variable from year to year. In shorter term studies, this variation in genetic merit may introduce bias to grazing system studies. This indicates a potential problem, although it is not a major bias in this study. Another point of interest is the effect that genetic merit of sire may have on the average genetic merit of the progeny. In 1982 and 1983, a high percentage of the calves in the rotationally grazed system were sired by 1 bull. This bull was deficient in genetic merit insofar as 205-d weight is concerned. His genetic value was −15.4 kg. The result was a rather extreme difference in the estimated genetic merits of calves reared in the 2 systems during these 2 years. Sampling error of this type can be a major source of experimental error in animal performance data.

Table 2. Intercepts and regression coefficients for the regression of 205-d wt, genetic value and environmental value on year.

	Intercept[1]	Regression coefficient[2]
205-d wt		
Pooled	−553	.39 (.62)
Rotational	265	−.02 (1.0)
Continuous	−1,370	.81 (.71)
Difference[3]	1,635†	−.83
Genetic value		
Pooled	−692	.35 (.15)*
Rotational	−433	.22 (.28)
Continuous	−950	.48 (.12)**
Difference[3]	−517	−.26
Environmental value		
Pooled	145	.04 (.59)
Rotational	719	−.26 (.81)
Continuous	−429	.33 (.81)
Difference[3]	1,148†	−.58

[1]Kg.
[2]Regression of 205-d wt, genetic value or environmental value on year (kg/year). Standard error in parentheses.
[3]Rotational - Continuous.
†$P<.10$.
*$P<.05$.
**$P<.01$.

Environmental Trend

The most accurate appraisal of the effect of grazing system on animal performance should result from an analysis of least squares means for contemporary groups or environmental values. The potential bias associated with differences in genetic merit no longer contaminates this assessment of animal performance. Mean environmental values are presented in Table 1. The regression of these least squares means on year of birth allows evaluation of environmental trend, i.e., the effect of change in environmental quality on the performance of the calf (Fig. 3). Environmental quality declined by .26 ± .81 kg per year in the rotationally grazed system while environmental quality improved .33 ± .8 kg per year in the continuously grazed system (Table 2). Results of analysis of covariance (regression of mean environmental values on year of birth) are presented in Table 2. Environmental trend was generally similar to phenotypic trend, indicating little difference in genetic trend. Rate of change in environmental quality was similar ($P>.25$) between the pasture systems. The continuously grazed pasture system was higher in quality ($P<.10$) than was the rotationally grazed system. The lack of difference in rate of change in environmental quality indicates that pasture grazing treatment had no effect on animal performance during 16 years of observation. The continuously grazed system was possibly of higher quality initially, and continued to be more desirable from the animal perspective. This difference was most likely due to location effect or differences in pasture quality independent of the grazing system. If differences existed due to grazing system, some improvement should be noted in animal performance over time.

Discussion

Estimation of genetic values is a widely used tool in the field of animal evaluation. When probably used, these procedures not only allow estimation of genetic values, but also provide a mechanism to estimate the effects of environmental factors on animal performance. In grazing systems studies, simple evaluation of animal weights may not be an adequate means to evaluate animal response to the grazing system treatment. These phenotypic observations result from 1) the genetic potential of the study animals and 2) the

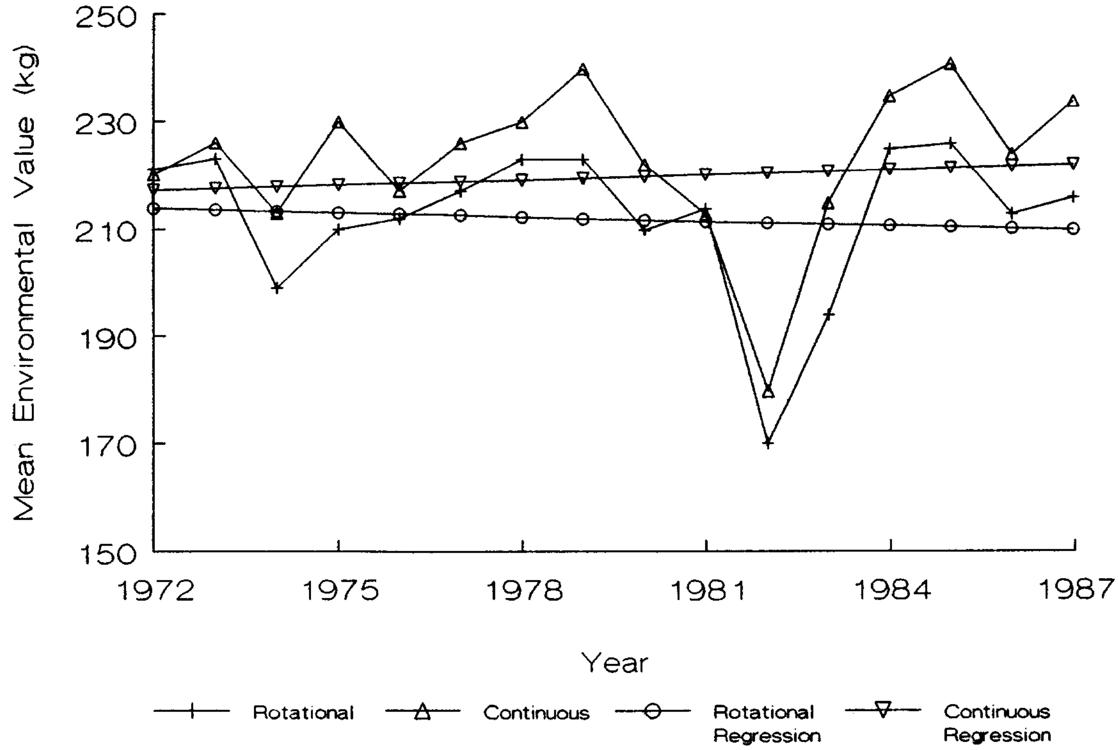

Fig. 3. Mean environmental value of Brangus heifer calves by year of birth in continuously and rotationally grazed pastures.

quality of the environment. The latter is the major point of concern in grazing systems studies.

In this study, change in genetic merit was similar in the 2 pasture systems. Genetic merit was also fairly evenly distributed between pasture systems. Although this is a potential bias in grazing system experimentation, it does not appear to be an important source of error in this evaluation. It should be noted that genetic merit and environmental effects are not estimated without error. The degree of potential error is determined by the amount of information available on each animal. Accurate use of these procedures requires relatively complete pedigree records as well as several generations of performance data. The omission of data on male calves in this study was necessary in order to avoid a bias due to castration. If males could have been utilized, the sensitivity of the analyses may have been improved. Males tend to be more susceptible to their environment, thus differences in treatment effects should be more detectable. The extreme variation in genetic merit between pasture systems, however, indicates the potential for biases, particularly in shorter-duration studies. Although isolation of environmental trend was not necessary in this study, use of the procedures described herein may be warranted in future grazing system experimentation. When properly used, these techniques should largely eliminate biases associated with allocation of genetic merit to study groups.

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