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Genetic aspects of diet selection in the Chihuahuan desert

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Abstract

Fecal microhistology and chemistry were used to evaluate botanical composition and quality of diets selected by Brangus cattle grazing Chihuahuan desert range in 3 seasons; fall: October, 1991; winter: January, 1992; and summer: July, 1992. Fecal samples were collected from 100 head in fall (58 2–8 year cows and 42 calves), 53 head (2–8 year-old cows) in winter, and 44 head (2–8 year-old cows) in summer. Paternal half sib analyses were used to estimate genetic and phenotypic variances and heritability estimates. Heritability is the proportion of total (phenotypic) variation which is due to additive genetic effects. The effect of sire within age was observed for percentage of *Aristida* spp. ($P = 0.01$), *Sporobolus* spp. ($P = 0.09$), total grasses ($P = 0.02$), *Croton pottsii* (Klotzsch) Muell.-Arg. ($P = 0.03$), and total forbs ($P = 0.02$) in fall diets. The number of grass species in diets was also affected by sire ($P = 0.03$). Heritability estimates were 0.87, 0.51, 0.78, 0.76, and 0.79 for percentages of *Aristida* spp., *Sporobolus* spp., total grasses, *Croton pottsii*, and total forbs, respectively. Heritability estimates for number of grass and forb species in fall diets were 0.68 and 0.26, respectively. Heritability estimates for winter samples were 0.40, 0.00, 0.37, and 0.27 for percentages of *Sporobolus* spp., total grasses, *Yucca elata* Engelm., and total shrubs, respectively. Heritability estimates for the number of grass and total species observed in winter diets were 1.11 and 0.47, respectively. Heritability estimates for percentages of *Bouteloua* spp., total grasses, *Croton pottsii, Dalea* spp., and total forbs in summer samples were 0.20, 0.55, 0.58, and 0.46, respectively. Heritability estimates for the number of grass and total species in summer diets were 0.49 and 0.79, respectively. These data suggest that genetic composition of beef cattle may affect diet selection under Chihuahuan desert conditions.

Key Words: range, diets, cattle, heritability

Diet selection on western ranges is a very complex system. Components of this system include the range ecosystem, seasonal effects, animal to animal training, managerial impacts, and the genetic composition of the herd. Past research has largely focused on learned behavior (Provenza and Balph 1987), seasonal effects (Rosiere et al. 1975a, Rosiere et al. 1975b), grazing systems (Walker and Heitschmidt 1989, Taylor et al. 1980, Pinchak et al. 1990), forage availability (Scarnecchia et al. 1985), range improvement practices (Beck 1974, Lopes and Stuth 1984), and range composition and soil type (Senft et al. 1985). Little research has focused on differences in genetic predisposition for diet selection within species or breed. Some differences have been noted between small ruminant breeds for diet selection (Warren et al. 1984). However, data on free grazing cattle are somewhat contradictory. Under fairly uniform range conditions in eastern Colorado, Walker et al. (1981) concluded that no differences existed in diets selected by Hereford, Angus × Hereford and Charolais × Hereford cows. However, under the more diverse conditions in the Chihuahuan desert, Herbel and Nelson (1966a, 1966b) observed some differences in diet selection and grazing activities between Hereford and Santa Gertrudis cows. Similarly Winder et al. (unpublished data) observed numerous differences in diets selected by Hereford, Angus, and Brangus cows and calves.

The objectives of this study were 1) to investigate the effect of sire on diet composition and 2) to estimate the heritability of diet selection behaviors of free grazing Brangus cattle in the Chihuahuan desert. Our hypothesis is that genetic composition of cattle affects diets selected under free-grazing conditions.

Materials and Methods

Study Area

This study was conducted during October, 1991; January, 1992; and July, 1992 at the New Mexico State University College Ranch about 40 km north of Las Cruces, N.M. A single 1,400-ha pasture was utilized for this experiment. The location is a typical Chihuahuan desert site with mean annual precipitation of 234 mm. The average mean precipitation during the 2 years of this study was 427 mm of which 209 mm fell during the months of July, August, and September. Annual mean temperature was 16°C. June was the hottest month with a mean temperature of 36.8°C, while January was the coldest month with a mean temperature of 13°C. Principle forage species in the study area were mesa dropseed (*Sporobolus flexuosus* [Thurb.] Rydb.), black grama (*Bouteloua eripoda* [Torr.] Torr.), tobosa (*Hilaria mutica* [Buckl.]Benth.), and leatherweed croton (*Croton pottsii* [Klotzsch] Muell.-Arg.). Other common plant species in the study area were broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britt. and Rusby), honey mesquite (*Prosopis glandulosa* Torr.), and soap tree yucca (*Yucca elata* Engelm.).

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Standing crop was estimated for grasses and forbs within 5 days of animal sampling. Four clippings were taken at each of 13 reference points in the study pasture. Reference points were 500 m apart in east-west direction and 1,000 m apart in north-south direction. At each reference point, a random direction and a random number of steps between sampling frames was determined. Plants were clipped at ground level within a 0.6 × 0.3 m frame at each sampling point (4 per reference point). Samples were separated by species and placed in paper bags labeled by species and sample number. Samples were dried in a forced air oven a 50°C for 96 hours. Standing crop was calculated by weighing each sample and summing across species.

Experimental Animals

Cattle utilized in this experiment were purebred 2–8 year-old Brangus cows and their suckling calves (Table 1). All cows were reared on the ranch through weaning. Postweaning management of heifers differed by year of birth. Cows which were born in 1984–1986 (6–8 year-olds) were developed on the ranch, whereas cows born from 1987 through 1990 (2–7 year-olds) were removed from the ranch at weaning and placed on irrigated pasture for approximately 6 months. Cows born in 1988–1990 were removed from the ranch before their initial calving at 2 years of age for approximately 90 days. During this time, they were either maintained on alfalfa hay or on irrigated pasture. Calf data utilized in this study were collected only in October of 1991. Calves were born between 1 January and 24 April 1991 and were weaned on 15 October 1991. The cows and calves were placed into a common pasture 2 weeks before initiation of sampling. The cows received no supplemental feed before or during the sampling period. On 8 October 1991, 7 January 1992, and 15 July 1992 all cattle were gathered by 0900 hours. Weights, heights, body condition scores, and fecal grab samples were taken from each cow in each period. Fecal grab samples (approximately .5–1 kg) were taken from calves only in the October period.

Table 1. Numbers of cows and calves by age and season and number of sires of cows and calves sampled during fall, 1991 and spring and summer, 1992.

	Fall			Winter		Summer	
Age[1]	Males[2]	Females[3]	Sires[4]	Females[3]	Sires[4]	Females[3]	Sires[4]
Years	(Numbers)						
1	18	24	4				
2		15	3	17	4	14	4
3		6	2	8	3	7	2
4		14	4	8	4	6	2
5		11	2	8	2	7	2
7		6	2	6	2	5	2
8		6	2	6	2	5	2
Total	18	82	12[a]	53	13[a]	44	13[a]

[1] Age of individual. Calves born in 1991 are listed as 1 year of age in fall period.
[2] Male suckling calves.
[3] Lactating cows (fall and summer), Dry pregnant cows (winter) or suckling heifer calves (fall).
[4] Sires of cows (fall, winter, and summer) and suckling calves (fall).
[a] Number of sires with offspring evaluated.

Laboratory Methods

Fecal samples were dried in a forced air oven at 50°C for 7 days then ground in a Wiley mill to pass a 1-mm screen. Percentage of fecal organic matter composed of nitrogen was determined by the Kjeldahl method and percentage of fecal organic matter composed of phosphorus was determined by spectrophotometric calorimetric method (AOAC 1984). Botanical composition of feces was determined by microhistology (Sparks and Malechek 1968, Holechek 1982, Holechek and Gross 1982, Dabo et al. 1986). Dried ground samples were sent to AAFAB Composition Laboratory Inc., Fort Collins, Colo. Samples were then soaked in hot water and household bleach and rinsed through a 200-mesh Tyler standard screen to remove solubles and extremely small nondiagnostic particles (Holechek 1982). Samples were then transferred to 2 microscope slides. Equal amounts of sample were allocated to each slide by use of a template with a small hole. Hoyer's solution (Baker and Warten 1952) was then applied to the slide and thoroughly mixed with the sample. Cover slides were then mounted. Twenty fields per slide of composite sample were examined at 100x magnification. Frequency addition procedures described by Holechek and Gross (1982) were used to calculate the percentage composition of undigested dietary components in the feces. Plant composition was categorized by species when possible. However, in the case of some species, only the genera were used in analyses.

Statistical Analyses

In all analyses, the dependent variables were percentages of a specific plant genera or species or the total number of species or general observed in fecal samples. When the incidence of a particular genus or species was quite low (less than 3%), the most common occurrence tended to be zero. This resulted in skewed or bimodal distributions. For this reason, species which occurred at very low frequencies in fecal samples were omitted from statistical analyses of percentages of genera or species only.

All analyses were conducted using the General Linear Models (GLM) procedures of SAS (1988). Data were analyzed within period. The statistical model differed slightly by period. The statistical model for analysis of fall data included age, sex, and sire within age. Winter and summer data were analyzed by a model which included age and sire within age. The model for the summer data was similar to the winter model but included calf birth date (day of year) as a covariate. In all 3 analyses, sire within age was considered a random effect. Dependent variables included the percentages of various botanical components observed in fecal samples, the number of grass and total species observed in fecal samples and the percentage of fecal organic matter made up by nitrogen and phosphorus.

Variance components, heritability estimates and standard errors were estimated by paternal half sib analyses as described by Becker (1985). The genetic relationship between paternal half sibs was assumed to be 25%. Heritability estimates indicate the proportion of total (phenotypic) variation (variance) which is additively genetic or due to transmittable genetic causes (Legates and Warwick 1990). These estimates are expected to range from 0 to 1.0. However, in small populations estimates may exceed 1.0 due to sampling.

Table 2. Raw means and percentages of total standing crop composed of by each plant species in study pasture in fall, 1991 and winter and summer, 1992[a].

Plant component	Fall		Winter		Summer	
	Mean (kg/ha)	%	Mean (kg/ha)	%	Mean (kg/ha)	%
Aristida adscensionis L.	43.5	5.6	39.9	7.2	0.0	0.0
Aristida divaricata Willd.	0.0	0.0	0.0	0.0	50.2	7.1
Aristida longiseta (Steud.) Vasey	35.1	4.5	7.1	1.3	22.5	3.2
Bouteloua barbata Lag.	2.0	0.2	15.9	2.9	0.0	0.0
Bouteloua eriopoda (Torr.) Torr.	329.3	42.1	272.3	49.3	239.8	34.1
Erioneuron pulchellum (H.B.K.) Tateoka	19.9	2.5	10.3	1.9	7.0	1.0
Enneapogon desvauxii Beauv.	2.6	0.3	0.0	0.0	0.0	0.0
Muhlenbergia porteri Scribn.	0.0	0.0	17.1	3.1	0.0	0.0
Panicum spp.	0.9	0.1	0.0	0.0	0.0	0.0
Scleropogon brevifolius Phil.	6.8	0.9	2.8	0.5	0.0	0.0
Sporobolus flexuosus (Thurb.) Rydb.	134.5	17.2	158.9	28.9	119.6	17.0
Sporobolus contractus A.S. Hitchc.	22.8	2.9	0.0	0.0	0.0	.0
Total grasses	597.4	76.3	524.3	95.0	439.1	62.4
Allionia incarnata L.	0.0	0.0	2.8	0.5	0.0	0.0
Astragulus spp.	4.7	0.6	0.0	0.0	6.8	1.0
Baileya multiradiata Harv. & Gray	3.7	0.5	0.0	0.0	16.2	2.3
Cassia bauhinioides Gray	2.4	0.3	0.0	0.0	0.0	0.0
Croton pottsii (Klotzsch) Muell. Arg.	40.6	5.2	4.6	1.0	68.5	9.7
Euphorbia spp.	8.9	1.1	0.0	0.0	6.8	1.0
Gutierrezia sarothrae (Pursh) Britt & Rusby	74.8	9.6	13.9	2.5	132.3	18.8
Hoffmanseggia jamesii Torr. & Gray	24.2	3.1	0.4	0.1	34.2	4.8
Lesquerella fendleri (Gray) Wats.	0.0	0.0	3.1	0.6	0.0	0.0
Pectis papposa Harv. & Gray	9.1	1.2	0.0	0.0	0.0	0.0
Perezia nana Gray	5.4	0.7	2.6	0.5	0.0	0.0
Solanum elaeagnifolium Cav.	3.7	0.5	0.0	0.0	0.0	0.0
Sphaeralcea coccinea (Pursh) Rydb.	7.7	1.0	0.0	0.0	0.0	0.0
Total forbs	185.4	23.8	27.4	5.0	264.8	37.6
Total grass and forbs	782.8	100	551.7	100	703.9	100

[a] Means of 52, 0.6 × 0.3 m frames.

Results

Standing crop estimates for the study pasture in each sampling period are indicated in Table 2. Grasses accounted for a larger percentage of standing crop in all seasons than forbs. Shrub species were present but were not included in standing crop estimates due to difficulty of estimation.

Fall Diet Composition

Sire was an important source of variation in percentage of *Aristida* spp. ($P = 0.01$), *Sporobolus* spp. ($P = 0.09$), total grass ($P = 0.02$), *Croton pottsii* ($P = 0.03$), and total forbs ($P = 0.02$) during the fall sampling (Table 3). Since the sire contributes only genetic material to his offspring, any sire effects are assumed to be genetic. Heritability estimates were 0.87, 0.51, and 0.78 for percentages of *Aristida* spp., *Sporobolus* spp., and total grasses, respectively. Similarly, heritability estimates for percentages of *Croton pottsii* and total forbs were 0.76 and 0.79, respectively. These estimates indicate that diet selection during this time period was greatly influenced by genetic variation within breed. The magnitude of the heritability estimates suggests that it may be possible to modify grazing behavior in this season through animal selection. The mean number of grass and total plant species detected in fecal samples were 4 and 7 species, respectively. The heritability estimates for these measurements were 0.68 and 0.26, respectively indicating that it may be possible to manipulate the number of plants selected by cattle genetically during the fall season. Fecal phosphorus and nitrogen percentages are used to indicate nutritional status of grazing cattle. Sire did not affect ($P > 0.80$) either of these measurements and heritability estimates were incalculable due to negative variance components.

Winter Diet Composition

No significant sire effects were noted for species composition of diets selected by dry, pregnant cows in January 1992. Heritability estimates were 0.40, 0.00, 0.37, and 0.27 for percentages of *Sprobolus* spp., total grasses, *Yucca,* and total shrubs, respectively (Table 4). On average, the genus *Bouteloua* spp. accounted for the largest proportion of diets (64.84%). However, there was no sire effect observed for this dietary component ($P = 0.83$), resulting in a negative estimate of genetic variance and an incalculable heritability estimate. As in fall, sire of cow affected ($P = 0.06$) the total number of grasses in diets. The effect of sire on total number of species in diets was somewhat less ($P = 0.24$). Heritability estimates were 1.11 and 0.47 for number of grass and total species, respectively. As in fall, sire of cow was not an important source of variation in fecal phosphorus or nitrogen. The total number of observations was less in winter than in fall, this resulted in larger standard errors of heritability estimates. Heritability estimates for percentages of *Sporobolus* spp., *Yucca,* and total shrubs strongly suggest that preference for these species may be under partial genetic control. Once again, diet diversity

Table 3. Sire effects, genetic and phenotypic variances and heritability estimates for composition of diets selected by Brangus cattle in fall, 1991.

Trait[1]	Overall mean	Sire OSL[2]	Genetic variance	Phenotypic variance	Herit.[3]	SE[4]
Percentages by Genera or Species						
Aristida spp.	3.20	0.01	14.2	16.4	0.87	0.52
Sporobolus spp.	31.11	0.09	160.9	313.7	0.51	0.49
Total Grasses	39.07	0.02	336.4	430.4	0.78	0.53
Croton pottsii	56.72	0.03	353.8	464.6	0.76	0.53
Total Forbs	60.76	0.02	339.0	428.8	0.79	0.53
Number of Species Detected						
Grasses	4.14	0.03	1.7	2.6	0.68	0.51
Total	6.97	0.21	1.0	3.7	0.26	0.43
Diet Quality Indicators[5]						
Fecal Phosphorus	0.32	0.95				
Fecal Nitrogen	2.16	0.84				

[1] N = 100.
[2] Observed significance level of sire within age.
[3] Narrow sense heritability estimate from paternal half sib analysis.
[4] Standard error of heritability estimate.
[5] Unable to calculate genetic variance and heritability due to negative variance components.

Table 5. Sire effects, genetic and phenotypic variances and heritability estimates for composition of diets selected by Brangus cattle in summer, 1992.

Trait[1]	Overall mean	Sire OSL[2]	Genetic variance	Phenotypic variance	Herit.[3]	SE[4]
Percentages by Genera or Species						
Bouteloua	7.96	0.35	6.6	32.0	0.20	1.03
Sporobolus[5]	53.88	0.48				
Total Grasses	71.56	0.28	72.2	130.7	0.55	0.92
Croton pottsii[5]	15.71	0.89				
Dalea	8.59	0.26	30.8	52.9	0.58	1.04
Total Forbs	27.42	0.31	61.4	131.9	0.46	1.02
Number of Species Detected						
Grasses	4.52	0.23	2.7	5.5	0.49	0.81
Total	7.57	0.14	11.8	14.9	0.79	0.82
Diet Quality Indicators						
Fecal Phosphorus	0.71	0.11	0.09	0.10	0.89	1.10
Fecal Nitrogen	2.27	0.20	0.09	0.06	1.47	0.98

[1] N = 44.
[2] Observed significance level of sire within age.
[3] Narrow sense heritability estimate from paternal half sib analysis.
[4] Standard error of heritability estimate.
[5] Unable to calculate genetic variance and heritability due to negative variance components.

(measured as the number of grass and total plant species detected) appears to be influenced by genetics. The magnitude of genetic effects appears to be somewhat less than observed in the fall sample. This may be due to lessened opportunity to express differences in preference due to limited availability of certain plants (Table 2).

Summer Diet Composition

Means, sire effects, variances, and heritability estimates for the July sampling period are indicated in Table 5. Sire was not a significant source of variation for diet composition, diversity and quality indicators. Heritability estimates for dietary composition components ranged from 0.20 for *Bouteloua* spp. to 0.58 for *Dalea* spp. once again suggesting that diet selection was influenced by the genetic composition of the animal. The diversity of the diet as indicated by the number of species detected also appears to be influenced by genetics. Heritability estimates for number of grass and total species detected were 0.49 and 0.79, respectively. In general, dietary components again appear to be moderately to highly heritable, however, the minimal effect of sire on *Sporobolus* spp. percentage in the diet resulted in negative variance components and an incalculable heritability estimate. Heritability estimates for the number of grass species and total species in diets were 0.49 and 0.79, respectively. Heritability estimates for fecal nitrogen and phosphorus were 0.89 and 1.47, respectively. This indicates that nutrient status may also vary with genetic composition of the herd. Though standard errors are large, these data strongly suggest that summer diet selection, diet diversity and diet quality may be affected by the genetic composition of cattle.

Table 4. Sire effects, genetic and phenotypic variances and heritability estimates for composition of diets selected by Brangus cattle in winter, 1992.

Trait[1]	Overall mean	Sire OSL[2]	Genetic variance	Phenotypic variance	Herit.[3]	SE[4]
Percentages by Genera or Species						
Bouteloua[5]	64.84	0.83				
Sporobolus	7.70	0.25	26.0	64.7	0.40	0.68
Total Grasses	86.01	0.46	0.1	70.4	0.00	0.63
Yucca	9.25	0.26	19.0	50.7	0.37	0.68
Total Shrubs	10.92	0.31	15.4	56.9	0.27	0.69
Number of Species Detected						
Grasses	3.91	0.06	0.9	0.8	1.11	0.82
Total	6.47	0.24	0.8	1.6	0.47	0.81
Diet Quality Indicators[5]						
Fecal Phosphorus	0.15	0.81				
Fecal Nitrogen	0.94	0.61				

[1] N = 53.
[2] Observed significance level of sire within age.
[3] Narrow sense heritability estimate from paternal half sib analysis.
[4] Standard error of heritability estimate.
[5] Unable to calculate genetic variance and heritability due to negative variance components.

Discussion

Large standard errors associated with heritability estimates are the result of a fairly small experimental population. True heritability, therefore, may reside within a fairly large interval around these estimates. Our heritability estimates were consistently high, indicating that additive genetic variation is a major component of the total variation in these traits. Furthermore, our data support the hypothesis that the species composition of diets and quality of diets selected are in part a function of the genetic composition of the animal.

Dietary behavior has generally been described as an acquired response to environmental stimuli such as seasonal changes, managerial inputs or active training. Genetic predisposition may be another important element in this complex system. In the Chihuahuan desert, utilization of the rangeland may be affected by differences in diet selection (Herbel and Nelson 1966a, 1966b, Winder et. al, unpublished data,). Diet selection may be affected by the genetic composition within breeds. If diet selection is related to animal performance (growth, milk production, reproductive efficiency, etc.) then improvement of these traits may result in changes in dietary habits. Other recent work at our station indicates that this may occur (Winder et. al, unpublished data,). Thus, livestock producers would benefit by selecting breeding stock from environments similar to those in which they will be expected to perform.

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