Fort Keogh
Livestock and Range
Research Laboratory

2005 Research Update

USDA-Agricultural Research Service
in cooperation with the
Montana Agricultural Experiment Station

United States Department of Agriculture
Agricultural Research Service
Fort Keogh
Livestock and Range Research Laboratory
in cooperation with
Montana Agricultural Experiment Station
243 Fort Keogh Road
Miles City, MT 59301-4016
Phone: 406-874-8200
Fax: 406-874-8289
Homepage: www.ars.usda.gov/npa/ftkeogh

Edited by Lance T. Vermeire.

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Introduction to Fort Keogh

ROD HEITSCHMIDT, RESEARCH LEADER

Fort Keogh was established by Congress as an Army Calvary post on July 22, 1876, approximately one month after the Battle of the Little Bighorn. The 100 section (64,000 acres) Fort was named after Captain Myles Keogh, an adjutant to General Custer at the Battle. The initial commander of Fort Keogh was General Nelson Miles for whom Miles City is named.

In 1907, all infantry troops were withdrawn from the Fort and in 1909 it was designated a Remount Station. Reportedly, more horses were processed at Fort Keogh than any other remount station during World War I. The Army relinquished the land in 1922 and following the complete withdrawal of all military personnel in 1924, Congress transferred Fort Keogh to the U.S. Department of Agriculture for the purpose of conducting agricultural research. The date of transfer was April 15, 1924. For a more detailed treatment of the Fort Keogh's military history, we recommend reading Josef Warhank's unpublished California State University Master of Arts thesis entitled *Fort Keogh: Cutting Edge of a Culture*, available on our website.

The earliest research at Fort Keogh focused on animal genetics and range management. At one time the Fort maintained purebred herds/flocks of Milking Shorthorn and Hereford cattle, Rambouillet ewes, Belgian, Morgan and Thoroughbred horses, Bronze turkeys and Wiltshire Side hogs. Gradually, the sheep, horse, turkey, milk cow, and hog research was phased out, with the last to go being the hog research in 1986. Today, the animal research herd is restricted to beef cattle and includes research conducted in three broad disciplines; genetics, reproductive physiology, and nutrition.

The earliest range research began in the 1930s under the direction of the U.S. Forest Service. This pioneering research focused on establishing "safe" winter and summer stocking rates for the Northern Great Plains. Today, the range management research is conducted in four broad disciplines; rangeland ecology, plant ecophysiology, weed ecology and range animal nutrition.

Fort Keogh currently consists of about 55,000 acres. About 50,000 acres are native rangeland, 2500 acres are dryland planted pasture, 1000 acres are irrigated pasture, and 700 acres are irrigated cropland. The remaining 800 acres are the headquarters area, corrals, etc. We have about 400 miles of fence and 220 miles of roads and trails. The irrigated farming operation produces about 3500 tons of alfalfa hay, 5000 tons of corn silage, 7500 bushels of barley grain, 150 tons of sorghum-sudan hay and an assortment of barley straw and grass hays that are used for livestock feed.

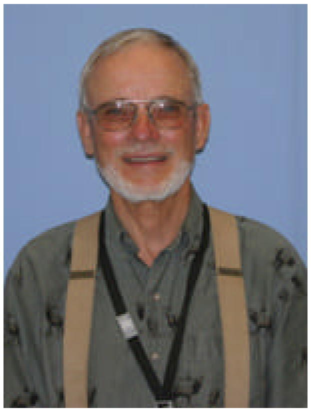
The beef cow herds consists of about 250 Line 1 Herefords, the oldest and purest line of Herefords in the world; 400 CGC's, a composite gene combination herd consisting of 50% Red Angus, 25% Tarentaise, and 25% Charolais; and about 750 mixed breeds cows. We have a modern 40,000 bushel feed mill and two feedlots that can accommodate about 1000 head of growing cattle.

The Fort Keogh staff consists of 27 USDA Agricultural Research Service (ARS) employees and 20 Montana Agricultural Experiment Station (MAES) employees plus 5 to 10 seasonal employees. The scientists and most of the technicians are ARS employees whereas the cowboy, farm, and maintenance crews are MAES employees. There are 10 scientists; 2 geneticists, 2 reproductive physiologists, 2 range animal nutritionist, and 4 rangeland scientists. In addition, the Montana State Extension Eastern Regional Department Head and Montana State Beef Cattle Extension Specialist are based at Fort Keogh.

Administration is a cooperative venture between the ARS and MAES in that ARS owns the land, facilities, and most of the equipment and MAES owns the livestock. Funding for the operation is through federal USDA appropriations and the sale of livestock. No State of Montana funds are used at Fort Keogh other than those funds realized from the sale of livestock.

Authors

Lee J. Alexander
Molecular Geneticicst



Marshall R. Haferkamp
Rangeland Scientist

Rodney K. Heitschmidt
Rangeland Ecologist
& Research Leader

Michael D. MacNeil
Quantitative Geneticist

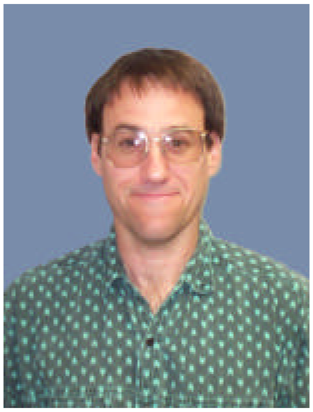
Jennifer M. Muscha
Rangeland Scientist III

Elaine E. Grings
Range Animal Nutritionist

Thomas W. Geary
Reproductive Physiologist

Matthew J. Rinella
Weed Scientist

Richard C. Waterman
Range Animal Nutritionist



Andrew J. Roberts
Reproductive Physiologist

Lance T. Vermeire
Rangeland Ecologist

Cooperating Authors

Ansotegui, R.P. - Animal & Range Sciences, Montana State University, Bozeman

Areseneau, J.D. - Animal Science, Perdue University, West Lafayette, IN

Branson, D.N. - Pest Management Research Unit, USDA-ARS, Sidney, MT

Brooke, R.C. - Fort Keogh Livestock & Range Research Laboratory, USDA-ARS, Miles City, MT (intern)

Burns, P.D. - Animal Science, Colorado State University, Fort Collins

Day, M.L. - Animal Sciences, Ohio State University, Columbus

DeJarnette, J.M. - Select Sires, Inc., Plain City, OH

Funston, R.N. - West-Central Research & Extension Center, North Platte, NE

Jiang, Z. - Animal Sciences, Washington State University, Pullman

Johnson, S.K. - Animal Sciences, Ohio State University, Columbus

Keisler, D.H. - Animal Science, University of Missouri, Columbia

Kesler, D.J.- Animal Sciences, University of Illinois, Champaign

Klement, K.D. - Frontier Natural Resource Consulting, Prineville, OR

Kruse, R.E. - Animal & Range Sciences, Montana State University, Bozeman

Lamb, G.C. - Animal Science, University of Minnesota, Grand Rapids

Landblom, D.G. - Dickinson Research Extension Center, North Dakota State University, Dickinson

Larson, J.E. - Animal Science, University of Minnesota, Grand Rapids

Lipsey, R.J. - American Simmental Association, Bozeman, MT

Marston, T.W. - Animal Sciences, Ohio State University, Columbus

Merrill, M.L. - Animal & Range Sciences, Montana State University, Bozeman

Paisley, S.I. - Animal Science, University of Wyoming, Laramie

Paterson, J.A. - Animal & Range Sciences, Montana State University, Bozeman

Perry, G.W. - Animal & Range Sciences, South Dakota State University, Brookings

Phillips, W.A. - Grazinglands Research Laboratory, USDA-ARS, El Reno, OK

Rose, J.L. - Range, Wildlife, & Fisheries, Texas Tech University, Lubbock

Schrick, F.N. - Animal Science, University of Tennessee, Knoxville

Sheley, R.L. - Range & Meadow Forage Research Laboratory, USDA-ARS, Burns, OR

Short, R.E. - Fort Keogh Livestock & Range Research Laboratory, USDA-ARS, Miles City, MT (retired)

Smith, M.F. - Animal Science, University of Missouri, Columbia

Stevenson, J.S. - Animal Sciences, Ohio State University, Columbus

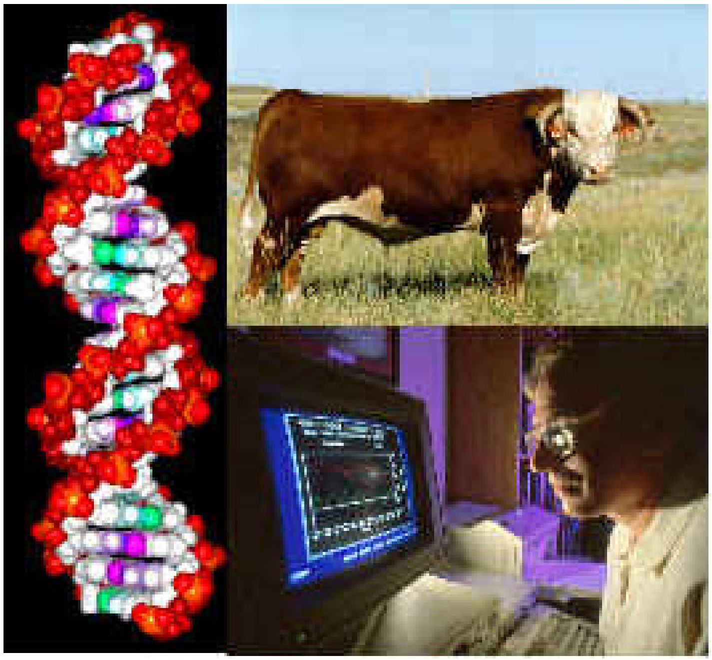
Tess, M.W. - Animal & Range Sciences, Montana State University, Bozeman

Thompson, B.D. - Miles City Veterinary Clinic, Miles City, MT

Wester, D.B. - Range, Wildlife, & Fisheries, Texas Tech University, Lubbock

Whittier, D. - Animal Science, Colorado State University, Fort Collins

Genetics Research



Update on the Bovine Genome Project

L.J. ALEXANDER

Problem: The genomes of mammals are very complex. Typically, mammalian genomes contain about 3 billion bases. Of these, only about 5% code for proteins, which are the functional units that define what we are and how we respond to our environment. Therefore, it is a huge undertaking to pinpoint which gene or genes are responsible for trait differences between animals or breeds. Often it is only the change of one base that causes the observed differences. The sequencing of the bovine genome is well underway and the animal that is being sequenced is Dominette, a Line 1 Hereford from Fort Keogh. The genome is divided into two parts: euchromatic (containing genes and functional elements), and heterochromatic (containing repetitive non-coding DNA) regions. The bovine sequencing project follows the human genome sequencing project that determined 99.9% of the DNA sequence of the euchromatic regions.

Procedure: Two technologies are being applied to obtain the final sequence. All of the DNA will be sheared randomly into 4,000 base pair segments and sequence reactions will be performed at each end of these segments. As of the end of March, approximately 27 million sequencing reactions had been performed, which corresponds to 20.2 billion bases. It is estimated the size of the bovine euchromatic region is approximately 3 billion bases. Therefore, we have 6.7 fold coverage of the genome. By coverage we mean that every base is sequenced 6.7 times on average. This redundancy is needed to help reassemble the genome from the 27 million sequenced fragments. The second technology used to assemble the genome is to take large segments (150,000 bases) of the genome and sequence these to a redundancy level of two-fold. These data will then be used as scaffold to complete the final assembly of the bovine genome.

Results: Assembly of the bovine euchromatic region is expected to be complete by June 2005. The final assembly of the bovine genome is estimated to be complete in January 2006. For more information and updates, see the Human Genome Sequencing Center, Baylor College of Medicine web site at http://www.hgsc.bcm.tmc.edu/projects/bovine/.

Implications: The final genome sequence will aid us greatly in defining and selecting the genes that are responsible for important traits in cattle.

Figure 1. The source for the bovine genome sequencing, L1 Dominette 01449, and calf at Fort Keogh.

Toward Understanding Variation in Fatness of Beef Cattle

M.D. MACNEIL, T.W. GEARY, Z. JIANG, D.H. KEISLER,
A.J. ROBERTS, L.W. ALEXANDER, AND E.E. GRINGS

Problem: Fat deposition directly affects value of beef carcasses. Excess fat depth over the 12th rib or kidney, pelvic, and heart (KPH) fat increase carcass USDA Yield Grade and as a consequence decrease carcass value. Conversely, increased marbling increases USDA Quality Grade and carcass value. Physiological and genetic understanding of causes for differences in fat deposition remains incomplete. Thus, an objective of our research has been to examine mechanisms that may ultimately control fat deposition.

Procedures: Blood samples were collected from: 1) CGC (½ Red Angus, ¼ Charolais, ¼ Tarentaise) steers that had been castrated at approximately 1 year of age and 2) Lean beef (LB: ½ Piedmontese, ½ CGC; ½ Limousin, ½ CGC; or ½ Hereford, ½ CGC) steers that were castrated at less than 60 days of age. Each blood sample was assayed to determine the concentration of the hormone leptin. Shortly after obtaining the blood sample, the steers were transported to a processing plant and harvested according to humane cattle-processing procedures. Hot carcass weight, fat depth over the 12th rib (backfat), marbling score, ribeye area and percent KPH fat were measured on each carcass. One inch thick loin steaks were obtained from the LB steer carcasses and Warner-Bratzler shear force was determined on each. These data were used to assess the association of circulating levels of leptin with the carcass traits.

Steers and heifers from an F_2 generation of ½ Wagyu and ½ Limousin were finished for a minimum of 4 months and harvested according to humane cattle-processing procedures. Eight to ten head of cattle were harvested weekly with steers and heifers harvested in alternate weeks. Hot carcass weight, fat depth over the 12th rib, marbling score, ribeye area and percent KPH fat were measured on each carcass. A blood sample was collected from each animal and DNA isolated from white blood cells. Five previously identified genes related to fat deposition were evaluated for the effect of alternative alleles on fat depth over the 12th rib. These candidate genes were: thyroglobulin, leptin, diacylglycerol O-acyltransferase 1, growth hormone, and fatty acid binding protein (heart) like 6.

Line 1 Hereford (L1) and CGC cows were bred to L1 x CGC crossbred bulls. After weaning, the resulting offspring were backgrounded until approximately 18 months of age and then moved to an individual feeding facility equipped with electronic feeding gates. Beginning about 90 days thereafter, 6 steers and 6 heifers were transported to a local abattoir each week and harvested according to humane cattle-processing procedures. Hot carcass weight, fat depth over the 12th rib, marbling score, ribeye area and percent KPH fat were measured on each carcass. A blood sample was collected from each animal, its parents, and paternal grandparents. DNA was isolated from the white blood cells. Microsatellite markers that spanned the genome were identified and each animal was genotyped. Genome maps were constructed and genomic locations where carcass traits were significantly affected by marker genotypes were identified.

Results: Average serum leptin concentration, fat depth, and marbling score were numerically lower in CGC steers than in LB steers. Correlations of serum leptin concentration with fat depth, marbling score, and percent KPH fat were positive (Table 1). Thus, within these groups, circulating concentrations of leptin appeared to indicate fat content of live cattle, with greater leptin concentrations being associated with greater fatness.

Table 1. Correlations of serum leptin concentration with measures of fatness in LB and CGC steers.

Group	Fat depth	Marbling score	KPH fat (%)
Lean Beef	0.34	0.35	0.42
CGC	0.46	0.50	0.56

One possible explanation for the phenotypic association between leptin and fatness just described is that alternative alleles of the leptin gene result in different circulating concentrations of the hormone. However, when this hypothesis was tested in Wagyu x Limousin cattle that were highly variable in fatness, no association was found between alternative alleles of the leptin gene and fat cover over the 12th rib. In this population, differences in fat deposition were associated with alternative forms of another candidate gene; one which codes for diacylglycerol O-acyltransferase 1. Three other previously discovered candidate genes that were evaluated also had little or no effect on fat cover over the 12th rib in Wagyu x Limousin cattle.

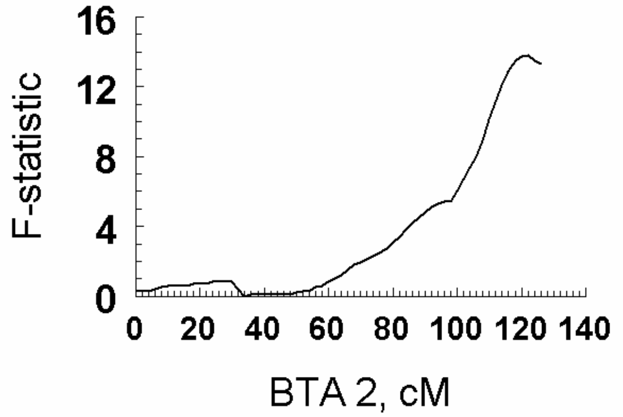


Figure 1. Magnitude of the effect (F-statistic) on marbling score of substituting an allele from Line 1 Hereford for an allele from CGC at various positions along bovine chromosome (BTA) 2.

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In addition to previously discovered genes which cause differences in fatness, the genomic location of other genes was investigated. Figure 1 illustrates the magnitude of a substantial genetic effect on marbling that originates from a gene or genes located on the telomeric end of chromosome 2. The peak of the plotted line indicates the most likely position of a gene or genes that influence marbling in beef cattle. To date, no candidate genes affecting fat deposition have been reported in this region.

Implications: Differences in fatness are important determinants of carcass value and may be related to maternal productivity. However, physiological and genetic understanding of causes for these differences remains incomplete. Further, the cause and effect relationship between genetics and physiology is poorly understood. It is apparent, from this work and the work of others that evaluation of allelic differences at a relatively small number of loci will not lead to a comprehensive characterization of differences in fatness among animals.

Related Publications

Geary, T.W., E.L. McFadin, **M.D. MacNeil, E.E. Grings**, R.E. Short, R.N. Funston, and D.H. Keisler. 2003. Leptin as a predictor of carcass composition in beef cattle. Journal of Animal Science 81:1-8.

MacNeil, M.D. and Grosz, M.D. 2002. Genome-wide scans for QTL affecting carcass traits in Hereford x composite double backcross populations. Journal of Animal Science 80:2316-2324.

Economic Evaluation of Terminal Sires for Use in Commercial Beef Production

M.D. MacNeil

Problem: Widespread use of expected progeny differences (EPD) to identify candidates for selection has centered primarily on growth. However, this strategy has done little to improve production efficiency or profitability. Producers have not had readily available tools to quantify the economic importance of various phenotypes. Further, it has been infeasible to rank potential sires based on expected differences in profit to be derived from their progeny.

Procedures: Numerous people have stressed the formal (mathematical) definition of a breeding objective (**H**) as an essential prerequisite to genetic improvement

$$\mathbf{H = ?\ v_i\, g_i}$$

In the preceding equation, $\mathbf{v_i}$ denotes the change in profit that results from a single unit change in phenotype of the i^{th} trait and $\mathbf{g_i}$ denotes the genetic value of the animal being evaluated for that trait. The $\mathbf{v_i}$ are often referred to as relative economic values. It has been shown that an EPD can be substituted for the $\mathbf{g_i}$ and produce an equivalent criterion for evaluation. The basic question is, "How much would profit change if any one EPD, and thus progeny phenotype, were changed by one unit?"

Given an appropriate genetic evaluation system to produce EPD, evaluating individuals for profit potential of their progeny depends on the ability to disentangle the contribution of phenotypes to profit. Profit occurs when income received for products exceeds the costs of inputs and resources used to produce those products. For beef cattle, the primary product is ultimately meat which may be valued per pound of carcass weight. Primary costs of beef production include feed, infrastructure and labor. Systems analysis techniques can be used to model a variety of beef production systems. The analysis may be further complicated by use of crossbreeding in the commercial production sector.

In this research, the choice of production systems to be simulated depended on visions of breed use developed in cooperation with breed associations and other partners. Breeding objectives specific to selection of terminal sires were developed for Angus, Hereford, Charolais, Limousin, and Simmental. The breeding objective for Angus envisioned a straightbred production system. The breeding objective for Simmental envisioned using Simmental sires on straightbred Angus females. Whereas, objectives developed for the other breeds were based on production systems that employed a terminal sire on females produced in two-breed rotational crossing system.

The model used is highly aggregated and relies on user inputs for the phenotypic characterization of the germplasm used and economic characterization of the production environment. It simulates a production system that is constrained in size by a fixed energetic resource being available for cow-calf production. Breed characterizations were taken from the literature. Phenotypes for: cow weight, milk production, female fertility, calf survival, weaning weight (direct effects), postweaning average daily gain, postweaning feed intake, days fed, dressing percentage, USDA Yield Grade, and marbling score were assumed to determine profitability. Number of calves produced was a function of male fertility, female fertility, and calf survival. Weaning weights were established as a base for the production environment. The feedlot phase was divided into three periods. The first period was terminated at a weight-constant endpoint of 850 lbs. The second and third periods were of 50- and 100-day durations, respectively. Energy density of rations fed increased with period, as did average daily gain. Feed conversion (feed/gain) decreased with periods. Carcasses are characterized on the tri-variate normal distribution of weight, marbling score, and cutability and their valuation results from price discrimination based on carcass weight, USDA Yield Grade, and USDA Quality Grade. Variable and fixed costs of cow-calf production were monitored. In the feedlot, fixed costs per day and feed costs were accumulated. Profit was computed as the difference between total carcass value and total cost. Genes from terminal sires influence progeny that are harvested, but not attributes of producing

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females. Thus, only phenotypes for: calf survival, weaning weight, postweaning average daily gain, postweaning feed intake, dressing percentage, USDA Yield Grade, and marbling score contribute to the breeding objectives.

Expected income and expense for a production system over a planning horizon were required. Cull cow price estimates were determined from USDA Market News 10-year average from Sioux Falls and the Food and Agricultural Policy Research Institute 10-year forecast for utility cows. Feeder steer price estimates were determined from 10-year average Oklahoma City price estimates and forecasted 10-year average, based on USDA Market News reports. Carcass quality grade, yield grade, and off-grade price estimates were based on *National Carcass Premiums and Discounts for Slaughter Steers and Heifers* as reported by USDA Market News service. Backgrounding and feeding cost estimates were based on 10-year average Kansas State University Extension *Monthly Performance, Cost of Gain, and Breakeven Prices*. These economic statistics were reviewed by the cooperating partners and adjusted slightly to be more consistent with their respective visions of future costs and values.

A baseline economic analysis was conducted using a computer model of a ranch-to-rail enterprise. Then, in separate simulations, the phenotype for each of the economically relevant traits was perturbed a single unit. The difference between simulated profit with a phenotype perturbed and profit in the baseline simulation was taken to be the relative economic value for that trait.

Results: For each breed, relative economic values associated with the phenotypes contributing to profitability are presented in Table 1. The relative economic values reflect differences in profitability of a beef production enterprise, as described above, that result from a unit increase in each of the traits. A primary source of the discrepancy between values for Angus relative to the other breeds results from the modeling of straightbred production for Angus. Thus, the Angus objective assumes the advantages of heterosis are not capitalized upon. All the other breed organizations accepted the use of crossbreeding to capture heterosis as an integral part of their envisioned production systems.

Differences in variation among phenotypes complicate comparisons of emphasis given to the various traits. Thus, presented in Table 2 are the relative economic values multiplied by their respective genetic standard deviations. To further simplify the comparison of genetic emphasis given to the various traits, the relative value for feed intake has been fixed at 1 for each breed.

Most notable of the general conclusions that can be drawn from the data presented in Table 2 is that no single trait dominates the breeding objective for any breed. However, calf survival is the single most important component of the breeding objectives for terminal sires despite its having low heritability. It is also notable that feed consumed during the feedlot phase of production is generally a more important contributor to genetic improvement in profitability than is growth during the same period. For Hereford and Angus, the balance in desired selection pressure between growth and carcass traits is shifted slightly in favor of the carcass traits. For the continental breeds, that balance is much more nearly equal and perhaps shifted slightly toward the growth traits.

Obviously, not all of the traits found to be important in these breeding objectives are routinely reported as EPD in the various systems for national genetic evaluation of beef cattle. However, given the body of research literature in which estimates of heritability and genetic correlation have been reported, it is feasible to map a set of EPD onto an objective. The lack of EPD that are closely related to economically relevant traits points toward needed additions to systems of national cattle evaluation.

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Table 1. Relative economic values for phenotypes associated with profitability of progeny produced by terminal sires of various breeds.

	Breed				
Trait	Angus	Charolais[1]	Hereford	Limousin	Simmental
	Relative economic value ($)				
Calf survival	1096.4	733.0	783.5	735.8	867.5
Direct weaning weight	130.3	145.1	138.0	146.0	102.0
Average daily gain	8956.6	5564.2	6719.1	7276.1	4082.0
Feed intake	-3546.8	-4074.3	-2644.1	-2552.4	-2645.9
Dressing %	2937.5	3319.0	2673.5	2760.0	1130.7
Yield grade	-10149.2	-284.4	-5896.0	-2986.8	-4119.6
Marbling	4761.0	58.4	4023.6	5490.0	1764.0

[1] The objective present here for Charolais is generic, whereas customized objectives can be produced by breeders using the tool available on the American International Charolais Association website.

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Table 2. Standardized economic values for phenotypes associated with profitability of progeny produced by terminal sires of various breeds (e.g., within Angus, calf survival is 5.5 times more important than feed intake).

	Breed				
Trait	Angus	Charolais	Hereford	Limousin	Simmental
Calf survival	5.5	3.2	5.2	5.1	5.8
Direct weaning weight	1.2	1.2	1.7	1.9	1.3
Average daily gain	0.6	0.3	0.6	0.7	0.4
Feed intake	1.0	1.0	1.0	1.0	1.0
Dressing %	2.1	2.1	2.6	2.7	1.1
Yield grade	2.0	<0.0	1.6	0.8	1.1
Marbling	1.4	<0.0	1.6	2.3	0.7

Implications: Using genetic selection to improve profitability necessitates emphasis be given to several traits simultaneously. Breeding objectives provide an objective guide by for the process. The breeding objectives for terminal sires that are reported here indicate the need for balanced consideration across an array of traits as opposed to placing most of the available selection pressure on only a couple of traits.

Related Publications

MacNeil, M.D. 2000. Engaging information: With the introduction of carcass EPDs, Charolais breeders need to know how all of this information can be used for better genetic selection. Charolais Journal p. 58.

Herring, W.O. and **M.D. MacNeil**. 2001. An overview of the 1999 Angus sire alliance. Proceedings of the Beef Improvement Federation.

MacNeil, M.D. 2005. Breeding objectives for Hereford cattle: Helping Hereford seedstock breeders improve profit for their commercial customers. Hereford World.

MacNeil, M.D. 2005. Breeding objectives for Angus cattle in South Africa and the United States. Proceedings of the 9th World Angus Forum, CapeTown, South Africa.

Genetic Evaluation of the Ratio of Calf Weaning Weight to Cow Weight

M.D. MacNeil

Problem: Nutritional cost of maintaining females is a substantial portion of input to beef production. The phenotypic ratio of weaning weight of a calf to weight of its dam may be an indicator of efficiency, and has been postulated to be a reasonable measure of economic utility of a commercial beef cow. Objectives of this research were to 1) estimate genetic parameters for the ratio of calf 200-day weight to mature-equivalent cow weight at weaning and other growth traits; and 2) evaluate responses to selection based on the ratio.

Procedures: This research made use of the CGC composite population of beef cattle developed at Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana. In 1989, a randomly selected and mated control line and a line selected for greater values of the ratio were established. Bulls for the selection line were selected based on 100 times the ratio of their age of dam adjusted 200-day weight to the coincident mature equivalent weight of their dam. Selection decisions were based on phenotypic performance within year. Virtually all selection pressure was applied to males, and most females were exposed for breeding as yearlings. Bulls for the control line were selected at random. All bulls were required to pass a breeding soundness examination as yearlings before being used for breeding.

A 45-day breeding season began on approximately June 15 each year. Cows were exposed for breeding in single-sire pastures until approximately August 1. After the breeding season, cows grazed native rangeland until vegetation was covered by snow. Cows were weighed and pregnancy tested when their calves were weaned in early October. Nonpregnant females were culled. Cows and heifers were managed separately through winter, with protein supplement provided when forage was available and hay fed when the forage was covered by snow. In preparation for calving, cows were moved to small pastures and fed approximately 20 lbs of alfalfa hay per cow daily. As calving approached, first-calf heifers were observed periodically throughout the day. Older cows were observed only during daylight. Cow weights were adjusted to a mature (5-year-old) equivalent basis using multiplicative adjustment factors derived from the data, first in 1987 and subsequently in 1990. The adjustment factors were 1.197, 1.110, and 1.045 for 2-, 3- and 4-year-old cows, respectively.

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Most calves were born during April and May of each year. Male calves were not castrated and no creep feed was offered to the calves. Calves were weaned at an average age of approximately 180 days. After weaning, the calves were moved to a feedlot for a 140-day evaluation of postweaning growth. Before the test period began, the calves were allowed a pre-test adjustment period of 2 to 4 weeks following weaning. Bull calves were fed a diet that was formulated to support an average growth rate of 3.1 lbs/day. Heifer calves were fed to gain 1.75 lbs/day. Birth weight and gain from birth to weaning were adjusted for differences in age of dam. Weaning and yearling weights were adjusted to age-constant bases as recommended by the Beef Improvement Federation.

Phenotypes evaluated in the selected and control lines were the ratio (n=4184), birth weight (n=5083), 200-day weight (n=4902), 365-day weight (n=4626), and mature-equivalent cow weight at weaning (n=4375). Data analyses were conducted using a multiple-trait Gibbs sampler for animal models.

Results: Mean estimates of direct and maternal heritability for the ratio were 0.20 ± 0.03 and 0.58 ± 0.05, respectively. The estimated posterior mean of the genetic correlation between direct and maternal effects was -0.77 ± 0.04. Permanent environmental effects due to females and residual effects, on average, accounted for 23 ± 3% and 25 ± 2% of phenotypic variance, respectively. No comparable partitioning of the variance of the ratio of calf weaning weight to cow weight was found in the literature. However, the strong genetic antagonism between direct and maternal genetic effects and the average posterior estimate of total heritability of 0.10 ± 0.02 foretell of challenges in the genetic improvement through selection based on phenotype.

Trends in direct and maternal genetic effects on the ratio are presented in Figure 1 for both the selected and control lines. The regressions of direct and maternal breeding values on generation number (-0.25 ± 0.23 and 0.52 ± 0.40, respectively) indicate no significant genetic change for the control line. For the ratio selection line, the regression of direct genetic effects on generation number (-0.02 ± 0.23) was not significant. However, the corresponding regression of maternal genetic effects on generation number (1.32 ± 0.38) indicated a significant positive genetic trend. As might be anticipated from the genetic trends, the ratio and control lines had diverged 2 ratio units at the end of the experiment (1998-2000).

Heritability estimates for direct 200-day weight and cow weight were 0.48 ± 0.03 and 0.76 ± 0.02, respectively. The genetic correlation between direct effects was 0.91 ± 0.02. The estimate of heritability of maternal effects on 200-day weight was 0.13 ± 0.02. The heritability of maternal effects on cow weight was essentially nil. Selection for the ratio may be considered as selection to simultaneously increase 200-day weight and decrease cow weight. This selection is in opposition to the positive genetic correlation between the component traits. As a consequence, the genetic correlation between 200-day weight and cow weight in a line selected for the ratio may be more positive after a few generations of selection than before and thus make long-term genetic change in the ratio even more difficult. The phenotypic correlation between 200-day weight and cow weight was 0.20.

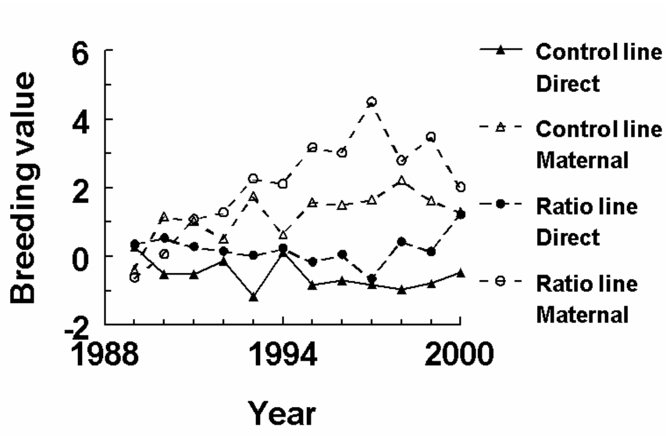

Figure 1. Trends in direct and maternal breeding values for the ratio of calf 200-day weight to mature-equivalent cow weight.

The regression of 200-day weight on cow weight after adjusting both weights for contemporary group effects was nonlinear and the Y-intercept of the regression line was positive, complicating interpretation of the ratio. Figure 2 illustrates the relationship between cow weight and 200-day weight of her calf as implied by the ratio relative to the relationship derived from the data via regression.

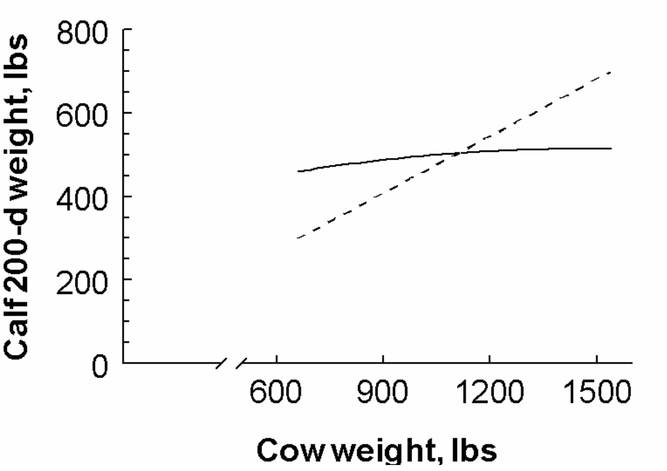

Figure 2. Relationships between 200-day weight of a calf and mature equivalent weight of the dam as measured by their phenotypic ratio (dashed line) and by regression of calf weight on cow weight (solid line).

As the ratio was considered a trait of the calf, the estimated maternal genetic effects on the ratio contain both genetic effects due to dams that environmentally affect performance of their progeny and direct genetic effects on the reciprocal of cow weight. Thus, the positive trend in maternal genetic effects on the ratio observed in the selected line may arise from both the positive genetic trend in maternal effects on 200-day weight and the non-significant, but complimentary, negative trend in direct effects on cow weight. However, no maternal

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genetic trend was observed for the ratio in the control line, as the significant negative trend in direct effects on cow weight was offset in part by a non-significant positive trend in maternal effects on 200-day weight.

Implications: Selection for a ratio is complicated by shifting emphasis given to the component traits. Phenotypic selection for the ratio of calf weaning weight to cow weight is further complicated by measurement of the two component phenotypes on different individuals and the consequent confounding of direct and maternal genetic effects on these phenotypes. Thus, selection index procedures would seemingly yield a better defined criterion with clear and consistent emphasis on the traits and their genetic components. This experiment illustrated the complexity of anticipating response to selection when the criterion is a ratio. Selection based on the ratio of calf weight to cow weight is not recommended.

Related Publications

MACNEIL, M.D. 2005. Genetic evaluation of the ratio of calf weaning weight to cow weight. Journal of Animal Science 83: 794-802.

Physiology Research

CIDRs Induce Estrous Cycles, Melengestrol Acetate (MGA) Does Not

T.W. GEARY, G.W. PERRY, AND M.F. SMITH

Problem: Estrous synchronization protocols that induce estrous cycles and result in consistently high pregnancy rates would improve acceptance of artificial insemination (AI) by commercial beef producers. Currently, about 30% of beef producers utilize AI in heifers, in part due to a proven method of synchronizing estrus. An estrous synchronization protocol that requires feeding melengestrol acetate (MGA) for 14 days followed by an injection of prostaglandin F_{2a} (PGF) 17 to 19 days later generally produces very good results. Use of a similar protocol in beef cows is generally ineffective because of the time interval required for implementation, but also because the ability of MGA to induce estrous cycles has been recently questioned. The US Food and Drug administration recently approved the use of CIDRs for synchronization of estrus in beef cows. The CIDR is an intravaginal insert that releases progesterone, while MGA is a feed additive that has progesterone-like properties. While MGA is relatively cheap to feed to cattle, the CIDR represents a considerable investment. One concern is that some producers might consider the CIDR and MGA to be interchangeable within estrous synchronization protocols. The objective of this study was to compare the effectiveness of the CIDR with MGA for induction of estrous cycles in postpartum anestrous cows and to determine the effectiveness of CIDRs or MGA for eliminating short estrous cycles following the first postpartum ovulation.

Procedures: One hundred mature beef cows were equally assigned to one of four treatments: CIDR (intravaginal insert containing 1.9 g progesterone), LM (low dose of MGA; 0.5 mg/head/day), HM (high dose of MGA; 4 mg/head/day), or Control by days postpartum, body condition, and body weight. Cows were an average of 30 days postpartum at the initiation of treatment. All cows were fed carrier (wheat mid pellets, 2.0 lbs/head/day) with (LM 0.55 mg MGA/kg, HM 4.41 mg MGA/kg) or without MGA (CIDR and Control treatments) for 7 days. Cows in the CIDR treatment received a new CIDR for 7 days. Estrous behavior was monitored continuously from day 0 until day 35 using HeatWatch (electronic mount detectors). All cows were bled 7 days before the initiation of treatment, and three times weekly from day 0 to day 35. An elevation of serum progesterone concentrations above 1 ng/mL was used as an indication of ovulation and initiation of estrous cycles. Cows with an increase in progesterone concentration before initiation of treatment were removed from the study.

Results: More CIDR-treated cows (90%) ovulated than LM (33%), HM (25%), or Control (41%) cows within 6 days following treatment. The number of cows that had ovulated did not differ among control, HM, and LM treated cows. In addition, more cows receiving the CIDR treatment (59%) exhibited standing estrus than cows receiving the LM (17%), HM (19%), or control (5%) treatments within 5 days of CIDR removal or MGA withdrawal (Fig. 1). The percentage of cows that exhibited standing estrus before the first postpartum ovulation (CIDR 65%, LM 57%, HM 35%, and control 30%) did not differ across treatments. None of the CIDR treated cows exhibited a short estrous cycle following the first ovulation postpartum. However, 77, 43, and 76% of LM, HM, and Control cows, respectively, exhibited a short estrous cycle following their first ovulation postpartum.

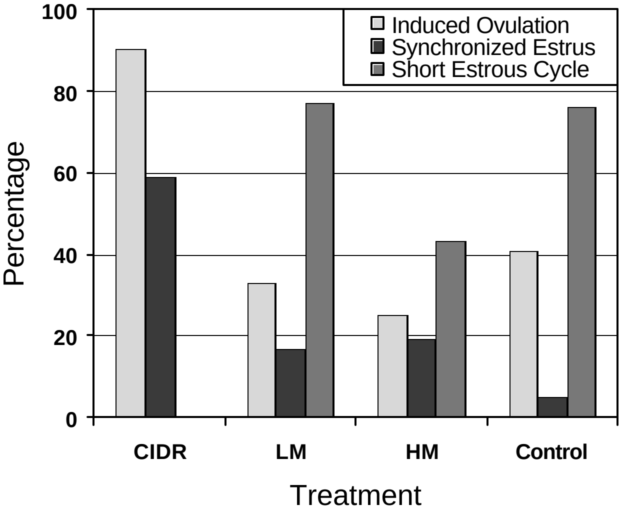

Figure 1. Percentage of receiving a CIDR, low MGA (LM), high MGA (HM), or Control treatment that ovulated (induced ovulation), had a synchronized estrus, and short estrous cycle following their first ovulation postpartum.

Implications: In the present study, treatment of early postpartum suckled beef cows with CIDRs induced ovulation and initiated estrous cycles of normal length. Treatment with MGA (normal or high dose) however, did not induce ovulation earlier than control treated cows, and did not decrease the percentage of cows with short estrous cycles following their first ovulation postpartum. Melengestrol acetate is not an acceptable substitute for the CIDR with respect to inducing estrous cycles, synchronizing estrus or preventing short estrous cycles following ovulation.

Related Publications

PERRY, G.A., M.F. SMITH, AND **T.W. GEARY**. 2004. Ability of intravaginal progesterone inserts and melengestrol acetate to induce estrous cycles in postpartum beef cows. Journal of Animal Science 82:695-704.

Using CIDRs and PGF_{2a} to Advance Date of Breeding in Postpartum Beef Cows

A.J. ROBERTS, T.W. GEARY, R.P. ANSOTEGUI,
J.A. PATERSON, J.L. OLSON, AND R.N. FUNSTON

Problem: Day of calving and length of postpartum anestrus are two major factors influencing profitability of beef cattle production. Day of calving has large affects on weight of calves at weaning and directly impacts the time a cow has to resume cycling prior to beginning the subsequent breeding season. On average, 23% of cows in beef herds have not ovulated by the start of breeding. If postpartum anestrus persists at initiation of breeding seasons, time of conception may be delayed or cows may fail to conceive during the breeding season, which increases the culling rate in herds and decreases net income of producers. Previous research has demonstrated that administration of progesterone or progesterone-like compounds (progestogens) to postpartum cows can initiate the resumption of reproductive cycles in anestrous cows. Objectives of this research were to evaluate the effectiveness of progesterone and estrous synchronization compounds in advancing date of breeding in cows under natural sire situations.

Procedures: A total of 297 cows from two ranches were grouped by age within location and were then randomly allotted to one of two groups (CIDR or Control). Cows in the CIDR group were implanted with the progesterone-releasing device on day 0 (beginning of a natural breeding season) and given an i.m. injection of 25 mg PGF_{2a} (Lutalyse) coincident with CIDR removal on day 7. Control cows received the i.m. injection of PGF_{2a} on day 7, without CIDR pretreatment. Body weight, body condition score and days postpartum were recorded for each cow on day 0. Cows at Location I averaged 3.4 years of age, 63 days postpartum, 1133 lbs, and were body condition score 4. Cows at Location II averaged 4.6 years of age, 58 days postpartum, 1076 lbs, and body condition score 4.74. Calves were maintained with cows at all times and allowed to nurse without restriction. Natural service was used in this study with bulls being introduced into each herd on day 0 and removed on day 60. Breeding pasture size was approximately 260 acres for Location I and approximately 220 acres for Location II. Bulls used at both locations passed breeding soundness examinations by a local veterinarian before initiation of the breeding season. Observations were made daily for the physical condition of the bulls for the duration of the first synchronized estrus. At Location I a yearling bull was used from day 0 to day 7 and eleven bulls were placed with cows on day 7 for a cow-to-bull ratio of approximately 19:1. At Location II, three, 3-yr old bulls were used throughout the breeding season, and an additional yearling bull was placed with the cows on day 3 of the breeding season for a cow-to-bull ratio of approximately 20:1.

Days to conception and number of estrous cycles to conception (21-day periods) were estimated by ultrasonography on days 66 and 73 and again by rectal palpation on days 176 and 123 for cows at Locations I and II, respectively. In cases where pregnancies were lost between the first and second diagnosis, these losses were accounted for in a final estimate of number of days or 21-day cycles required for conception. Two blood samples were collected from each cow to measure circulating concentrations of progesterone to determine which cows were cycling at the beginning of the study.

Results: At Location I, 76% of cows were cycling before the onset of treatment and at Location II, 54% of cows were cycling before the onset of treatment. Days to conception differed between the two ranches (Table 1). When combined across ranches, days to conception and number of estrous cycles for conception tended to decrease with CIDR treatment when evaluated before accounting for pregnancy losses between the first and second pregnancy diagnosis (Table 1). The number of pregnancies lost between first and second pregnancy diagnosis, did not differ between CIDR (7) and control (8). After accounting for these losses, no beneficial CIDR

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Table 1. Mean number of estrous cycles to conception (21-day periods), final number of estrous cycles for pregnancy (includes losses between first and second pregnancy diagnosis), days to conception, and days to final pregnancy at Locations I and II and for CIDR (CIDR + PGF_{2a}) and Control (single i.m. injection PGF_{2a}) treatments.

	Avg. estrous cycles to conception	Avg. estrous cycles to final pregnancy	Avg. days to conception	Avg. days to final pregnancy
Location				
Ranch 1 (224 cows)	$1.43 \pm .05^{a}$	$1.59 \pm .07^{a}$	20.6 ± 1.2^{a}	24.0 ± 1.5^{a}
Ranch 2 (73 cows)	$1.76 \pm .11^{a}$	$1.79 \pm .14^{a}$	30.1 ± 2.7^{a}	30.6 ± 3.2^{a}
Treatment				
CIDR	$1.53 \pm .07^{b}$	1.73 ± .09	23.9 ± 1.7^{b}	25.9 ± 2.1
Control	$1.66 \pm .07^{b}$	1.86 ± .09	26.9 ± 1.7^{b}	28.8 ± 2.0

[a] Cycle or day means differ between locations ($P < 0.001$).
[b] Cycle or day means differ between treatments ($P < 0.13$).

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effect was observed for day of final pregnancy or cycle of pregnancy. Overall pregnancy rates were not different between CIDR (94.6%) and control groups (93.2%).

Pretreatment of postpartum beef cows with a CIDR did not advance date of conception or improve pregnancy rates compared to a single injection of PGF_{2a} day 7 after initiation of the breeding season. Using the CIDR + PGF_{2a} treatment to synchronize cattle is more expensive than using a single injection of PGF_{2a}, and more labor intensive. Further studies are needed to determine if CIDR would be beneficial in beef cattle herds with a higher incidence of anestrus, there was not evidence indicating that the CIDR treatment worked better in one location than the other in the present study.

Implications: While numerous studies indicate that exogenous progestins may hasten return of estrus in postpartum cows and thereby advance date of breeding and over all conception rate, application of a CIDR + PGF_{2a} protocol to postpartum cows subjected to natural breeding did not show improvements in these traits in the present study, when more than 50% of the cows were cycling at the onset of the breeding season. While it is possible that a larger number of animals and more locations may demonstrate a statistical advantage of such progestin treatments, especially if the proportion of anestrous cows exceeds those observed in the present study, the cost of the CIDR treatment will be an important consideration in determining benefits for producers.

Synchronizing Estrus in Beef Heifers with a CIDR: A Multi-location Study

T.W. GEARY, J.E. LARSON, G.C. LAMB,
J.S. STEVENSON, S.K. JOHNSON, M.L. DAY, R.P.
ANSOTEGUI, D.J. KESLER, J.M. DEJARNETTE,
D.G. LANDBLOM, AND D. WHITTIER

Problem: Protocols for synchronization of estrus in beef heifers are somewhat limited. The method generally used for synchronizing estrus among heifers is the Melengestrol Acetate/prostaglandin F2a (MGA/PGF) protocol. Although excellent pregnancy rates can be achieved by using the MGA/PGF protocol, the time from initiating the protocol until breeding is more than 33 days, and this protocol generally requires feeding MGA in a feed bunk, as consumption is often inconsistent among heifers on pasture. Protocols using gonadotropin hormone-releasing hormone (GnRH) with PGF have been evaluated in heifers with unsatisfactory results. In addition, no reliable fixed-timed artificial insemination (TAI) protocol exists for synchronizing estrus in beef heifers. The CIDR was recently approved by the U.S. Food and Drug Administration for synchronizing estrus in replacement beef heifers. The CIDR is a vaginal insert that contains 1.38 g of progesterone, which is gradually released over a period of 7 days. The objectives of this study were to determine whether a TAI protocol could yield similar fertility rates to a protocol requiring detection of estrus and whether an injection of GnRH at CIDR insertion enhances pregnancy rates.

Procedures: Replacement beef heifers (n=2077) from 12 locations were assigned randomly to each of four estrous synchronization protocols (Fig. 1). All heifers received a CIDR for 7 days, and an injection of PGF on the day of CIDR removal. For treatment EAI, 517 heifers were observed for estrus for 84 hours after PGF administration and were inseminated about 12 hours after observed estrus. Any heifer not detected in estrus by 84 hours was injected with GnRH, followed by TAI. For treatment GnRH+EAI, 504 heifers were treated as those for EAI, but also received GnRH at the time of CIDR insertion. For treatment TAI, 531 heifers received a single TAI at 60 hours after PGF administration. For treatment GnRH+TAI, heifers 525 were treated as those for TAI, but also received GnRH at CIDR insertion. Blood samples were collected 7 and 17 days before the injection of PGF. Blood sera were analyzed for progesterone concentration to determine cycling status. Body condition scores were assessed 17 days before the injection of PGF. Clean-up bulls were not introduced until a minimum of 10 days after TAI. Pregnancy was diagnosed by transrectal ultrasonography 30 to 35 days after AI. The statistical model to evaluate pregnancy rates included treatment, location, and cycling status, with body condition score as a regression variable.

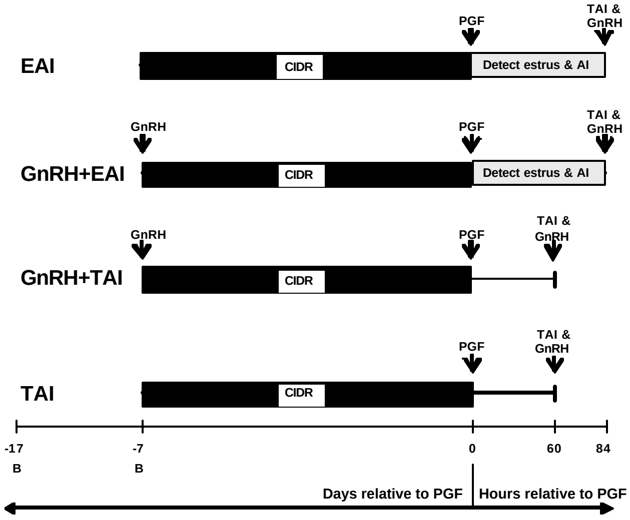

Figure 1. Schematic of experimental protocols for replacement beef heifers treated with GnRH, PGF, and a CIDR.

Results: Percentage of heifers cycling at the initiation of estrous synchronization was 91% (1350 of 1518 heifers). Percentages of cycling heifers among locations ranged from 78 to 100%. Overall pregnancy rates at days 30 to 35 after AI ranged from 38 to 74% across locations (Fig. 2). Pregnancy rates were 57, 55, 53, and 49% for GnRH+EAI, EAI, GnRH+TAI, and TAI, respectively (Fig. 3). Although no differences in pregnancy rates were detected among treatments, heifers that were inseminated in the estrous detection treatments (EAI and GnRH+EAI; 56%) had greater pregnancy rates than heifers in the TAI treatments (TAI and GnRH+TAI; 51%). Pregnancy rates for heifers bred following detected estrus before 84 hours (EAI and GnRH+EAI), were 44.6 and

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45.0%, respectively. The clean-up TAI at 84 hours enhanced pregnancy rates by 9.9 and 12.3 percentage points for EAI and GnRH+EAI treatments, respectively. These results indicate that clean-up TAI after a period of estrous detection enhances the potential for improving pregnancy rates to exceed those of 84-hour estrous detection alone. The time from PGF injection to detection of estrus, and to AI for those heifers exhibiting estrus, was similar between EAI (49.9 and 61.7 hours, respectively) and GnRH+EAI (49.8 and 61.3 hours, respectively) treatments.

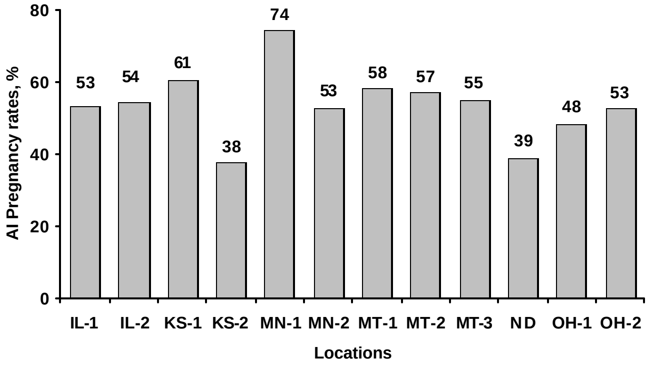

Figure 2. Distribution in overall pregnancy rates among locations for replacement beef heifers treated with GnRH, PGF, and a CIDR.

Implications: Our results demonstrate that estrus in heifers can be synchronized effectively with GnRH, PGF, and a CIDR. The GnRH+EAI treatment most frequently produced the greatest pregnancy rates and provided a reliable alternative to a protocol based on MGA and PGF. The GnRH+TAI protocol provided pregnancy rates that may be acceptable for producers wishing to use TAI alone.

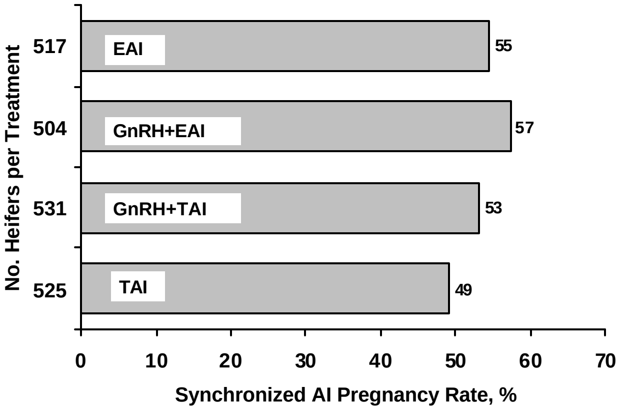

Figure 3. Pregnancy rates (%) for replacement beef heifers treated with GnRH, PGF, and CIDR (See Figure 1 for description of protocols).

Related Publications

LARSON, J.E., G.C. LAMB, **T.W. GEARY,** J.S. STEVENSON, S.K. JOHNSON, M.L. DAY, D. J. KESLER, J.M. DEJARNETTE, AND D.G. LANDBLOM. 2004. Synchronization of estrus in replacement beef heifers using GnRH, prostaglandin F_{2a} (PG), and progesterone (CIDR): A multi-location study. Journal of Animal Science 82 (Suppl. 1):368-369.

Synchronizing Estrus in Beef Cows with CIDRs: A Multi-location Study

T.W. GEARY, A.J. ROBERTS, J.E. LARSON, G.C. LAMB,
J.S. STEVENSON, T.W. MARSTON, S.K. JOHNSON,
M.L. DAY, D.J. KESLER, J.M. DEJARNETTE,
F.N. SCHRICK, AND J.D. ARESENEAU

Problem: Estrous synchronization protocols that yield tight synchrony and consistently high pregnancy rates in lactating beef cows are lacking. In addition, adoption of AI for beef cows would increase if an effective protocol were developed that yielded high pregnancy rates to fixed-timed artificial insemination (TAI). The CIDR was recently approved by the U.S. Food and Drug Administration for synchronizing estrus in beef cows. The CIDR is a vaginal insert that contains 1.38 g of progesterone, which is gradually released over a period of days, and it can be used effectively with prostaglandin F2a (PGF) with or without gonadotropin releasing hormone (GnRH) to synchronize estrus or ovulation in beef cows. The objectives of this study were to determine whether a TAI protocol could yield pregnancy rates similar to a protocol requiring detection of estrus and whether inclusion of a CIDR in protocols using GnRH and PGF would enhance fertility.

Procedures: Five estrous synchronization protocols using PGF with GnRH and (or) a CIDR were each assigned randomly to 2630 postpartum suckled beef cows from 14 locations. Protocols were Control, CO-Synch, CO-Synch+CIDR, Hybrid-Synch, and Hybrid-Synch+CIDR (Fig. 1). Cows received 1.) a CIDR insert for 7 days, with 25 mg of PGF on the day of CIDR removal, followed by detection of estrus and AI for 84 hours, with any cow not detected in estrus by 84 hours receiving 100 µg of GnRH and a clean-up TAI at 84 hours (Control); 2) 100 µg of GnRH, followed in 7 days with 25 mg of PGF, followed in 60 hours by a second injection of GnRH and TAI (CO-Synch); 3) CO-Synch plus a CIDR during the 7 days between the first injection of GnRH and administration of PGF (CO-Synch+CIDR); 4) 100 µg of GnRH, followed in 7 days with 25 mg of PGF, followed by detection of estrus and AI for 84 hours, with any cow not detected in estrus by 84 hours receiving 100 µg of GnRH and a clean-up TAI at 84 hours (Hybrid-Synch); and 5) Hybrid-Synch plus a CIDR during the 7 days between the first injection of GnRH and administration of PGF (Hybrid-Synch+CIDR). There were 511, 551, 547, 513, and 508 cows in Control, CO-Synch, CO-Synch+CIDR, Hybrid-Synch and Hybrid-Synch+CIDR treatments, respectively.

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Blood samples were collected 7 and 17 days before the injection of PGF. Blood serum was analyzed for progesterone concentration to determine cycling status. Body condition scores were assessed 17 days before the injection of PGF. Pregnancy was diagnosed by transrectal ultrasonography between 30 and 35 days, and again between 80 and 100 days after AI. Clean-up bulls were not introduced until a minimum of 10 days after TAI. The statistical model to evaluate pregnancy rates included treatment, location, cycling status, parity, and body condition scores, with days postpartum as a regression variable.

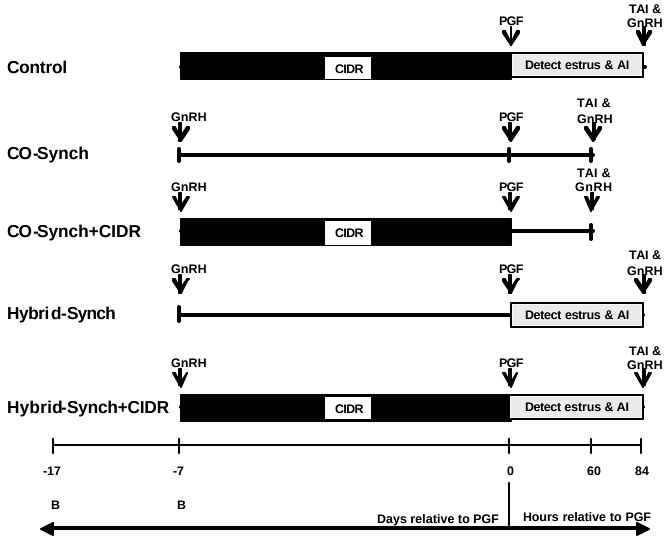

Figure 1. Schematic of experimental protocols for suckled beef cows treated with GnRH, PGF, and a CIDR.

Results: Percentage of cows cycling at the initiation of treatments was 67% (1534 of 2296 cows). Percentages of cycling cows ranged from 38 to 90% among locations. The greatest pregnancy rates were achieved by using the Hybrid-Synch+CIDR (58%) treatment. Although pregnancy rate with Hybrid-Synch+CIDR was not significantly different from the CO-Synch+CIDR (54%) and Hybrid-Synch (53%) treatments, it was greater than the Control (52%) and CO-Synch (43%), which yielded the poorest pregnancy rate (Fig. 2).

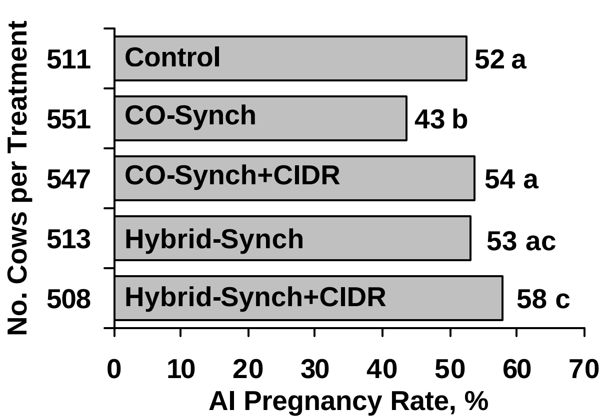

Figure 2. Pregnancy rates (%) to AI for lactating beef cows treated with GnRH, PGF, and(or) CIDRs

Perhaps the lesser pregnancy rate associated with CO-Synch was a result of delaying the TAI to 60 hours compared with previous reports in which timed AI was at 48 hours, when pregnancy rates between 47 and 52% were reported. In addition, overall pregnancy rates at days 30 to 35 ranged from 39 to 67% across locations (Fig. 3).

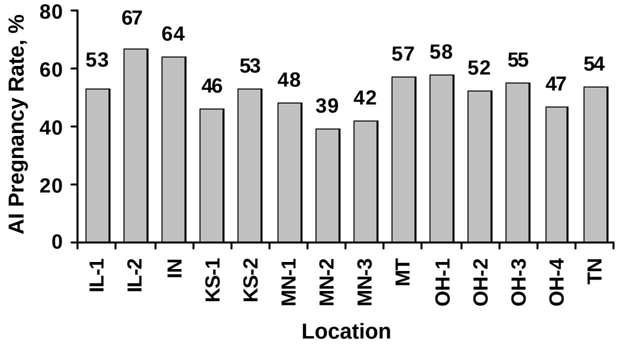

Figure 3. Distribution in synchronized AI pregnancy rates across locations for suckled beef cows rreated with GnRH, PGF, and(or) CIDRs.

For the protocols in which estrus was detected (Control, Hybrid-Synch, and Hybrid-Synch+CIDR), pregnancy rates for cows inseminated after detected in estrus were 37.1, 40.7, and 44.8%, respectively. Additional cows that conceived after the clean-up TAI at 84 hours enhanced pregnancy rates by 15.2, 12.3, and 13.1 percentage points for Control, Hybrid-Synch, and Hybrid-Synch+CIDR treatments, respectively. These results indicate that addition of TAI to breeding by estrus alone for 84 hours would yield greater pregnancy rates than protocols involving a short period of detected estrus without the clean-up TAI. In addition, the time from PGF injection to detection of estrus, and to AI for those cows exhibiting estrus, was similar among Control (52.6 and 64.0 hours, respectively), Hybrid-Synch (51.4 and 63.6 hours, respectively), and Hybrid-Synch+CIDR (53.5 and 65.2 hours, respectively).

Implications: Producers have several good options for synchronization of estrus and AI in suckled cows; the options differ in treatment costs and labor requirements. For a strict fixed-timed AI protocol, the CO-Synch+CIDR protocol yielded pregnancy rates greater than 50% at 9 of 14 locations. The treatment that most consistently yielded the greatest pregnancy rates was the Hybrid-Synch+CIDR treatment, with pregnancy rates greater than 50% at 10 of 14 locations.

The Use of Prostaglandin F to Synchronize Estrus in Beef Cattle and Influence Calving Dates

R.C. BROOKE, A.J. ROBERTS, AND T.W. GEARY

Problem: For cow-calf producers, weight of calves at market time has major influences on gross receipts from calf sales. While many management and genetic options are available to maximize calf weight at market time, it is crucial that the costs of these options do not exceed the increase in price received for the additional weight. Increasing the proportion of cows that calve at the beginning of the calving season is one option that can affect market weight by simply providing more calves a longer growing period before being sold on any given day. Estrous synchronization is commonly used in beef cattle to control receptivity and therefore, alter distribution of calving. Previous research has shown that use of estrous synchronization caused earlier calving by 13 days, and an increase of 21 lbs per calf in weaning weight. Assuming eastern Montana calf markets pay approximately one dollar per pound, an average 21-pound increase per calf is a $21 increase in gross profit per calf. Synchronization provides tight grouping of calving dates when compared to unsynchronized animals, allowing 14.9% of cows to calf on the peak day and 62.4% to calf during the peak week. This shift from the expected distribution could theoretically allow a rancher to shorten the calving season and shift calving dates toward the beginning of the season. The cow herd could also benefit by having a longer period between calving and the subsequent breeding season. Objectives of this research were to determine if a single injection of prostaglandin given to heifers 6 days after the beginning of a natural breeding season would alter calving distribution and thereby increase weight of calves at weaning.

Procedures: One herd of 104 Angus yearling heifers (Herd 1) and two mixed breed herds, containing 39 (Herd 2) and 48 (Herd 3) animals each were used for this research. Heifers from the three herds were randomly assigned into control (94 animals) and treatment (97 animals) groups within each herd. All heifers were exposed to four 2-year-old Hereford bulls on June 4, 2002. The treatment group animals were each given one dose of PGF on June 10. Herd 1 heifers were given 2 cc Estrumate, while Herds 2 and 3 were given 5 cc of Lutalyse. After the prostaglandin injections, Herd 1 was moved to a 2232-acre pasture with the four Hereford bulls. Herds 2 and 3 were placed together in a separate 2296-acre pasture with four yearling Angus bulls. The bulls were left in the pastures for 43 days after the PGF shot was given. Angus bulls were pulled from Herds 2 and 3 on July 23 and the Hereford bulls were pulled from Herd 1 on July 24. Heifers were pregnancy tested using ultrasound 51 days after bulls were removed and a visual body condition score from 1 to 10 was assigned. Calving began on March 11 and ended May 14, 2003 (65 days). Birth weight was recorded at birth. Herd 1 calves were again weighed on June 4 and Herd 2 and 3 calves were weighed on June 5.

Results: Mean birth dates and weights were similar between control and treatment animals (3/29/2003 +/- 13.6 days and 78.9 +/- 10.1 lbs, respectively). However, slight differences in calving distribution were noted. Treated animals initially experienced a greater number of calves born earlier. However, this apparent gain was lost on the 16th day (March 27, 2003) of the calving season (Fig. 1). Control animals continued to birth calves relatively steadily over time while treated animals experienced a slowed rate of calving during days 11-20 of the calving season (March 22 to March 31).

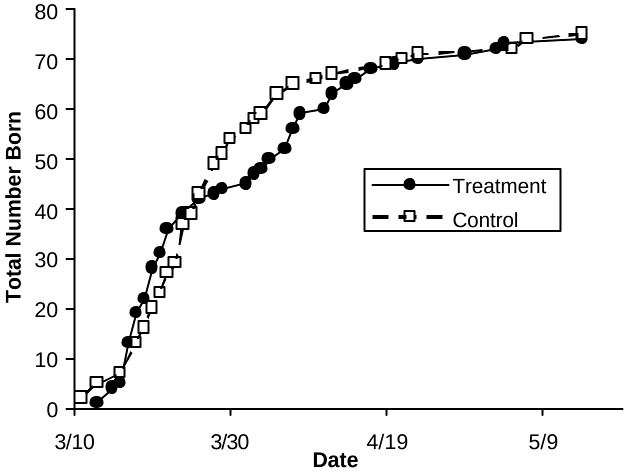

Figure 1. Calving distribution of control and treatment groups.

To examine the data more closely, calving dates were divided into 21-day periods, representative of the length of one estrous cycle. Period one was further broken down into 10- and 11-day segments, because the prostaglandin treatment would be expected to skew calving toward the first 10 days if effective. During the first 10 days, 32% of treated cows calved versus 24% of controls. However, during the second 11 days, 34% of the control cows calved versus 14% of the treatment cows (Fig. 2). These results indicate that the prostaglandin treatment did skew the calving distribution. More calves were born within the control group than the treated group during the first period (60 vs. 46% of treated vs. control heifers exposed for breeding). In contrast, 25% of all treated cows calved in the second 21-day period, while 15% of control cows calved during this time. Our interpretation of these results is that either fertility of the synchronized estrus in the treated group was less than the natural heats in the control, or the number/fertility of bulls used was not sufficient to accommodate the large number of heifers exhibiting estrus during the period of synchronized heats.

To provide additional insight into possible reasons for reduced fertility in treated heifers, differences in body condition score, birth weight, and pregnancy rate were examined among the herds (Table 1). Body condition score and birth weight differed between herds. These data emphasize the need to account for herd variation when performing these types of studies. Overall, Herd 1 was slower to calf than the other two herds. When response to treatment was evaluated across herds, it became apparent that treatment response in Herd 1differed from the other two herds (Fig. 3).

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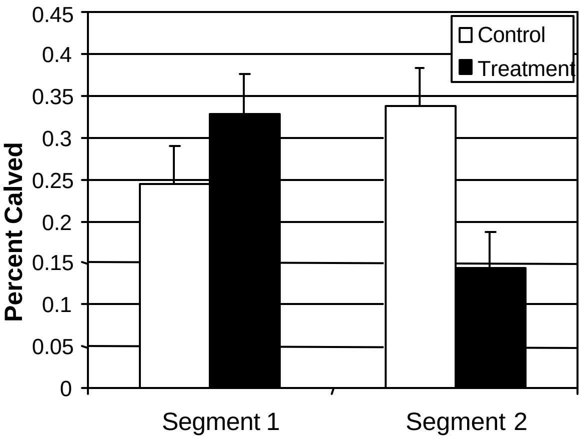

Figure 2. Percentage of heifers calved of total exposed, in 10 and 11-day segments of the first 21-day period of calving.

Mean age of calves at the time when they were weighed in June was 68 days and did not differ by treatment. Neither weight (average 222 lbs) nor average daily gain (2.13 lbs/day) differed between treatments. Average daily gain did vary across herd, as shown in Table 1.

Table 1. Values for BCS, birth weight, and pregnancy rate. Standard error analysis revealed some significant differences in herd, emphasized the need to account for herd in statistical models.

	Herd 1	Herd 2	Herd 3
Body condition score	5.6±1	6.4±1	6.1±.1
Birth weight (lbs)	80.4±1.14	77.5±1.82	76.5±1.63
% calving 1st 21-days	48+5	57+8	60+7
% calving 2nd 21-days	21±4	23±6	15±6
% calving 3rd 21-days	8±2	0	4±3
Average daily gain of calves (lbs)	2.28	2.02	1.92

It is apparent from Figure 1 that treatment with prostaglandin altered calving distribution. However, results indicate that the alterations did not increase calf weights, likely due to inefficiency in getting heifers pregnant at the synchronized heats. The decreased percentage of heifers that calved in the treated group during the first 21-day period could be attributed to the inability of bulls to service all heifers in heat within 5 days following the PGF injection, a problem that varied due to herd. Herd 1 was composed of Black Angus, while the other two herds were crossbred animals. These crossbred animals may have experienced a heterosis advantage that could have resulted in earlier pregnancies, which would be reflected by higher percentage of heifers calving in the first part of the calving season. In addition, differences between the bulls used for breeding of Herd 1 from those used for Herds 2 and 3 may also contribute to the observed differences in calving distribution. The ratio of heifers to bulls for Herd 1 was 26:1 while the ratio for Herds 2 and 3 was 22:1. Pasture shape and accessibility could be other factors contributing to decreased number of calves born within the first 21 days in the treatment group, due to the urgency and number of heifers in heat that the bull must service.

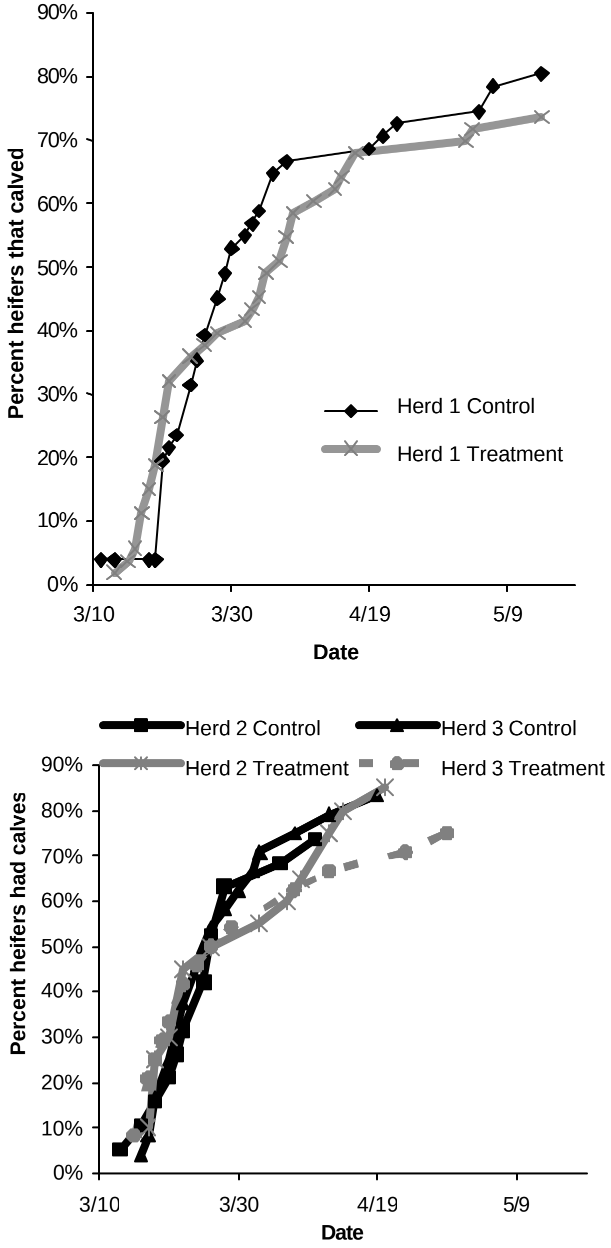

Figure 3. Percent of heifers calved by treatment in Herd 1 (top panel) or in Herds 2 and 3.

Implications: To make prostaglandin treatment with natural mating a cost effective method for altering calving distribution, one may consider the use of older more experienced bulls, rotation of bulls, or cow-to-bull ratios closer to 20:1. In addition, smaller pastures allowing for greater chance of bull-to-cow contact could be beneficial.

Does Flunixin Meglumine Improve Pregnancy Establishment in Beef Cattle?

T.W. GEARY, A.J. ROBERTS, R.C. WATERMAN,
M.D. MACNEIL, E.E. GRINGS, R.P. ANSOTEGUI,
B.D. THOMPSON, AND R.J. LIPSEY

Problem: It is estimated that fertilization is successful in 90 to 95% of cows that are bred regardless of whether this mating is by natural service or AI. However, conception rates to a single service are generally less than 65 to 75%, suggesting that embryonic loss occurs in 15 to 30% of females. This loss has been characterized, but is difficult to measure because the most reliable means of pregnancy diagnosis (ultrasound visualization of a fetal heartbeat) is not discernable until approximately 27 days after breeding. It is hypothesized that the majority of embryonic loss occurs because the developing embryo produces insufficient interferon tau to signal its presence around day 14 following breeding, resulting in failure of maternal recognition of pregnancy. Without sufficient interferon tau, the uterus produces prostaglandin F_{2a} (PGF), which causes corpus luteum regression and loss of progesterone secretion, allowing the female to return to estrus.

Flunixin meglumine (FM) is a non-steroidal anti-inflammatory compound that inhibits PGF synthesis. Administration of FM at the time of transportation stress 12 to 15 days after AI increased pregnancy rates by 15% over transported cows not receiving FM and by 8% over non-transported controls (Merrill et al., 2003). No differences in concentration of the metabolite of PGF (PGFM) were detected in serum collected from cows before or after a 5 hour trucking stress (± FM) or the control treatment, but transportation-stressed cows receiving FM experienced the greatest decrease in PGFM between the pre- and post-treatment blood samples. In a subsequent study, heifers and cows that received FM approximately 14 days after AI (± trucking stress) had higher AI pregnancy rates than heifers and cows receiving no FM (± trucking stress). The objective of this study was to determine effects of a single injection of the PGF inhibitor flunixin meglumine approximately 13 days after AI on pregnancy establishment in the absence of transportation stress.

Procedures: In Experiment I, 1221 predominantly Angus heifers were divided within five locations to receive FM or no further treatment (Control). At insemination, heifers were divided into two similar pastures or pens and approximately 13 days later, one group of heifers within each location was worked through an animal handling facility to administer FM (0.5mg/lb BW, i.m.) treatment. Immediately after FM, these heifers were placed in the same pasture as control heifers and bulls were introduced for the remainder of the breeding season. Pregnancy to AI was diagnosed among heifers approximately 35 days after AI using transrectal ultrasonography.

In Experiment II, 719 Angus cross cows within two locations received FM or Control treatment as described in Experiment I. At insemination, Control and FM cows were divided into separate pastures and only FM cows were handled after AI. Immediately after FM, these cows were placed into the same pasture as control cows and bulls were introduced for the remainder of the breeding season. Pregnancy to AI was diagnosed approximately 47 days after AI using transrectal ultrasonography.

In Experiment III, 247 heifers and 335 cows from one location were assigned at AI to receive FM or Control treatment approximately 13 days later. The genetic composition of cows and about one-half of the heifers in this experiment was CGC Composite (½ Red Angus, ¼ Charolais, ¼ Tarentaise), while the remaining heifers were predominantly Angus. All cows and heifers were handled through a working facility, but only half of each age group received FM treatment. Bulls were not introduced into either age group of cows until after day 13. Pregnancy was diagnosed approximately 29 days after AI using transrectal ultrasonography.

Results: In Experiment I, pregnancy rates to AI were reduced among heifers that were worked through a chute and given FM (65%) compared to Control heifers (71%; Table 1). Pregnancy rates were numerically higher for Control heifers compared to FM heifers across all locations (Table 1). Because the interval from AI to FM treatment varied based on interval to estrus following synchronization, we evaluated the effect of interval from AI to FM on pregnancy rate, but detected no effect (data not shown). Others have reported increased pregnancy rates when FM was administered to cattle after AI or at the time of embryo transfer. However, controls in those studies were also worked through a chute, in contrast to Experiment I where all heifers were not handled and exposed to stress after AI.

Table 1. Pregnancy rate to AI for heifers in Experiment I that received Flunixin Meglumine (FM) or no further treatment (Control) approximately 13 days after AI.

	AI pregnancy rate No. pregnant/total No. (%)		
Location	FM	Control	Combined
Bair	51/74 (69)	57/74 (77)	108/148 (73)
Peterson	42/62 (68)	51/68 (75)	93/130 (72)
Rumph	119/193 (62)	132/198 (67)	251/391 (64)
Swanz	51/74 (69)	58/77 (75)	109/151 (73)
Wang	130/202 (64)	143/199 (72)	273/401 (68)
Total	393/604 (65)^a	441/617 (71)^b	834/1221 (68)

In Experiment II, pregnancy rates to AI did not differ between FM (57%) and Control cows (58%; Table 2). We anticipated an increase in pregnancy rate among cows based on earlier studies. In contrast to Experiment I, where pregnancy rates were reduced in heifers that were processed through a chute and given FM when compared to non-disturbed controls, this treatment did not appear to adversely affect pregnancy in cows. Thus, it is possible that heifers may have been more sensitive than cows to either the stress of handling and (or) negative effects of FM injection, or that FM was effective at alleviating the stress of handling in cows, but not heifers.

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Table 2. Pregnancy rate to AI for cows in Experiment II that received Flunixin Meglumine (FM) or no further treatment (Control) approximately 13 days after AI.

	AI pregnancy rate No. pregnant/total No. (%)		
Location	FM	Control	Combined
Peterson	65/143 (45)	57/126 (45)	122/269 (45)[a]
Wang	152/236 (64)	141/213 (66)	293/449 (65)[b]
Total	217/379 (57)	198/339 (58)	415/718 (58)

In Experiment III, pregnancy rates to AI did not differ between FM (45%) and Control cows (42%) or FM (56%) and Control (55%) heifers. The design of Experiment III differed from Experiments I and II in that all heifers and cows were gathered and processed through a working facility in Experiment III, but only the FM females were processed in Experiments I and II.

When the results are considered from the 3 experiments, a logical conclusion is that processing of heifers through a chute about 14 days after breeding causes sufficient stress to reduce pregnancy rate (as observed in FM-treated heifers in Experiment I). However, similar responses were not observed in cows (Experiment II). In addition, it appears that treatment of heifers with a single i.m. injection of 1.1 mg FM/kg BW was not affective at alleviating the negative affects of processing in heifers because no benefit of FM was observed in Experiment III, where both Control and FM were processed. Other researchers have reported that stress from transportation at critical periods following breeding can affect pregnancy establishment. Cortisol concentration in serum collected before transportation from heifers was higher than that of cows. Transportation for 2.5 to 3 hours resulted in an approximate two-fold increase in cortisol concentration among cows, but very little increase in cortisol concentration among heifers. Thus, it would appear gathering and handling may be perceived as a greater stressor to heifers than to cows, which may have become more accustomed to handling stress. In earlier studies, FM-treated heifers and cows had higher pregnancy rates to AI than heifers and cows that did not receive FM regardless of whether they received transportation stress. Serum concentration of PGFM decreased after FM treatment of these cows and heifers. Serum collected from heifers before transportation or FM treatment had higher concentrations of PGFM than cows, and FM resulted in a sharper decrease in PGFM concentrations among transportation stressed heifers. Associations between PGFM and cortisol in heifers and cows may indicate one mechanism by which stress occurring around the time of maternal recognition of pregnancy may decrease pregnancy rates. Based on differences in response to FM after AI in the present study, a likely interpretation would be that FM administration may decrease embryonic loss among cows and heifers experiencing unavoidable stress by suppressing PGF concentrations in the bloodstream. However at the dosage evaluated in the present studies, a single administration of FM cannot improve pregnancy establishment above that of non-stressed females.

Implications: During maternal recognition of pregnancy, the embryo must prevent PGF release by the uterus in order to survive. Subjecting cattle to stressors, such as handling stress, may be sufficient in some females to interfere with embryonic inhibition of PGF. Experiments reported here provide evidence that handling stress may interfere with this process more in heifers than cows. A single injection of Flunixin Meglumine (1.1 mg/kg BW, i.m.) was inadequate to overcome the impacts of stress.

Related Publications

MERRILL, M.L., R.P. ANSOTEGUI, N.E. WAMSLEY, P.D. BURNS, AND **T.W. GEARY**. 2003. Effects of flunixin meglumine on embryonic loss in stressed beef cows. Proceedings of the Western Section, American Society of Animal Science 54:53-56.

MERRILL, M.L., R.P. ANSOTEGUI, J. A. PATERSON, AND **T.W. GEARY**. 2004. Effect of Flunixin Meglumine on early embryonic mortality in stressed beef females. Proceedings of the Western Section, American Society of Animal Science 55:304-307.

Use of hCG After Artificial Insemination to Improve Conception Rates in Heifers

R.N. FUNSTON, R.J. LIPSEY, T.W. GEARY,
AND A.J. ROBERTS

Problem: Early embryonic mortality decreases pregnancy rates in a limited breeding season, resulting in calves being born later in the calving season with lighter weights at weaning. Early embryonic mortality may be as high as 30% with a majority of losses occurring between days 8 and 16 of gestation. It is thought that insufficient luteal production of progesterone is associated with this early infertility in cattle. Administration of the hormone hCG during the early luteal phase has been shown to increase progesterone and improve conception rates in dairy herds of low fertility. The objective of this study was to determine if administration of hCG approximately 5 days after AI would increase plasma progesterone concentrations and thereby decrease early embryonic mortality resulting in improved conception rates in beef heifers.

Procedures: Heifers from two locations (Location I, 347 heifers; Location II, 246 heifers) received MGA (0.5 mg/heifer/day) for 14 days and an injection of PGF_{2a} (25 mg i.m.) 19 days later to synchronize estrus. Heifers were observed for estrus continuously during daylight from 0 to 4.5 days after PGF_{2a} and inseminated by AI approximately 12 hours after onset of estrus. Half of the heifers inseminated at Location I were randomly assigned to receive an injection of hCG (3333 IU i.m.) 8 days after PGF_{2a} and a blood sample was collected from all heifers 14 days after PGF_{2a} for progesterone analysis. Half of the heifers inseminated at Location II were administered hCG on day 9 after PGF_{2a} and a blood sample was collected from all heifers 17 days after PGF_{2a}. Pregnancy status was determined by ultrasound approximately 50 days after AI.

A second experiment was conducted at a third location to determine the effects of hCG administration 6 days after timed insemination in beef heifers. One hundred eighty beef heifers, approximately 14 months of age were fed MGA for 14 days and given 25 mg PGF_{2a} i.m.18.5 days later to synchronize estrus. All heifers were then time inseminated beginning approximately 60 hours after PGF_{2a} and given an injection of GnRH (gonadorelin, OvaCyst, Phoenix Scientific, St. Joseph, MO). Six days after AI, half of the heifers were randomly assigned to receive 3333 IU i.m. of hCG. Bulls were placed with heifers 10 days after AI for 45 days and pregnancy was determined by ultrasound 47 and 85 days after AI.

Results: Heifers at Location I had a 94% synchronization rate, exhibited estrus 2.45 ± 0.03 days after PGF_{2a} and received hCG 5.55 ± 0.03 days after AI. Heifers at Location II had an 85% synchronization rate, exhibited estrus 2.69 ± 0.03 days after $PGF_{2a,}$ and received hCG 6.31 ± 0.03 days after AI. Heifers at Location II had a delayed estrous response compared to heifers at Location I, and therefore were given hCG a day later than originally planned in an effort to target hCG administration 5 days after the peak AI period. Concentrations of progesterone were greater for hCG-treated heifers at both locations, 8.6 vs. 4.6 ng/mL for treatment vs. control at Location I and 11.2 vs. 5.6 ng/mL for treatment vs. control at Location II. There was no effect of hCG administration in relationship to days after AI on concentrations of progesterone at either location. At Location I, conception rate of hCG treatment (65%) and control (70%) groups were similar. However, conception rates at Location II tended to be increased by hCG treatment (61%) compared to control (50%). At Location I, pregnancy rate of hCG treatment (80%) and control (77%) groups were similar. Pregnancy rates at Location II tended to increase with hCG treatment (72%) compared to control (62%). Time of hCG administration in relation to day of AI did not affect conception rates.

In the second experiment, pregnancy rate to AI did not differ between hCG-treated (62%) and control heifers (59%) and final pregnancy rate (92%) also was not affected by treatment. There were also no pregnancy losses from the first to second pregnancy diagnosis for either treatment. It was hypothesized that hCG may be of more benefit in a timed AI protocol because it has been reported that induction of ovulation of follicles $\leq$ 12 mm resulted in the formation of luteal tissue with normal luteal life spans but decreased luteal function (Perry et al., 2002). The pregnancy rates in this study were very acceptable and therefore, it does not appear that decreased luteal function or embryonic mortality was a problem in these heifers.

Implications: It has been previously reported that progesterone treatment increased fertility in herds with low fertility, and this is consistent with the positive effect of hCG treatment at Location II, where conception rate of the controls was lower than the other two locations. Thus, administration of hCG 5 to 6 days after AI may improve conception and pregnancy rates in situations where conception rate falls below 60%. Perhaps insufficient progesterone is not a major factor contributing to early pregnancy failure in heifers when conception exceeds 60%, as was observed in the two locations where no benefit of hCG was observed.

Preventing Pregnancy Losses in Cattle Exposed to Transportation Stress

T.W. GEARY, M.L. MERRILL, R.P. ANSOTEGUI,
AND P.D. BURNS

Problem: Producers using artificial insemination (AI) often need to transport cattle to summer pastures afterward. The timing of transport can have negative effects on pregnancy establishment and maintenance. Beef heifers transported 8-12 or 29-33 days after AI had lower synchronized conception rates than those transported 1-4 days after AI. When transportation is not feasible early after breeding, producers are faced with the dilemma of transporting cows and heifers when an AI or subsequent pregnancy is at risk of being lost. Most would choose to transport cattle after the AI pregnancy is at a reduced risk, but we have witnessed 6% pregnancy loss in transported heifers that are 45 to 60 days pregnant.

Maternal recognition of pregnancy in cows begins around 14 days after fertilization and PGF secretion must be suppressed during maternal recognition of pregnancy. Elevated PGF secretion after day 6 following conception may interfere with maternal recognition of pregnancy. The adrenal hormone cortisol is commonly used as an index of stress. A possible mechanism by which increased cortisol might initiate pregnancy loss would be through increased prostaglandin $F_{2\alpha}$ (PGF) production.

Flunixin meglumine is a potent nonsteroidal, anti-inflammatory agent that inhibits cyclooxygenase preventing synthesis of PGF. Flunixin meglumine is commercially available and recognized by the trade name Banamine. A single injection of flunixin meglumine suppressed PGF in the blood for at least 24 hours. The objectives of these studies were to determine if flunixin meglumine administration would reduce early embryonic mortality in cows and heifers subjected to transportation stress, and to determine the effects of a single administration of flunixin meglumine on serum cortisol and PGF concentrations.

Procedures: In Experiment I, 97 mature Angus-cross cows were utilized. Approximately 14 days following a synchronized AI, cows were assigned to treatments by AI sire, AI date, and AI technician. Treatments were control (CON), induced stress (S), and induced stress with flunixin meglumine (SFM). The cows receiving CON remained at the ranch with their calves and were provided access to water but no feed for 4 hours. Cows receiving S and SFM were transported via semi-tractor trailer for 4 hours. Before transportation-induced stress, SFM treated cows received flunixin meglumine (0.5 mg/lb, i.m.). At the beginning and completion of treatment, rectal temperatures were recorded and blood samples collected from all cows for measurements of cortisol and PGF metabolite (PGFM) concentrations. Cows were exposed to clean-up bulls for 30 days, beginning the day after treatment. Transrectal ultrasonography was used to determine AI pregnancy status 55 to 57 days post-AI.

In Experiment II, 259 yearling, Angus-cross heifers were utilized and in Experiment III, 127 Angus-cross cows were utilized. Approximately 14 days following synchronized AI, females in Experiments II and III were randomly assigned to treatments: control (CON), control with flunixin meglumine (CONFM), transportation stress (S), and transportation stress with flunixin meglumine (SFM). The heifers or cows receiving CON and CONFM remained at the ranch and were provided access to water, but no feed for 5 hours (NTS). Heifers or cows receiving S and SFM were transported via semi-tractor trailer for approximately 5 hours (TS). Before transportation-induced stress, SFM and CONFM treated cows and heifers received flunixin meglumine (0.5 mg/lb, i.m.). Before treatment, blood samples were collected from all females for measurements of serum cortisol and PGFM concentration. A second blood sample was collected from all females after approximately 2.5 hours of transportation stress (or NTS treatment) and again after another 2.5 hours of transportation stress (or NTS treatment). Females were exposed to clean-up bulls for 30 days, beginning the day after treatment. Transrectal ultrasonography was used to determine AI pregnancy status for heifers at 33-35 d or for cows at 55-57 d post-AI.

Results: In Experiment I, AI pregnancy rates were 76, 69 and 84% for CON, S and SFM cows, respectively (Fig. 1). Pregnancy rates for the entire breeding season were 97 % for each treatment. Serum cortisol concentrations increased from the pre-treatment sample to the post-treatment sample in CON cows, but decreased in S and SFM cows (Fig. 2). Serum cortisol concentrations were not different between S and SFM treated cows. Serum PGF metabolite (PGFM) concentrations increased from the pre-treatment sample to the post-treatment sample in CON cows, but were unchanged in S cows and decreased in SFM cows (Fig. 2).

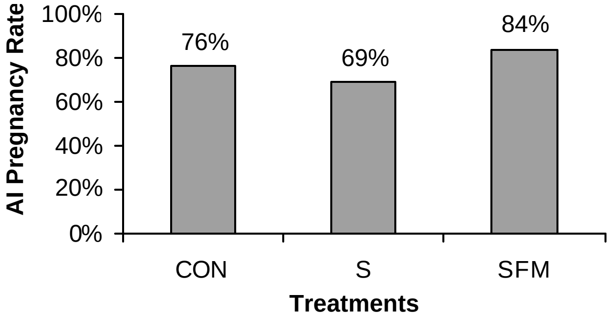

Figure 1. Pregnancy rate to AI for control cows (CON) and cows that received 4 hours transportation stress (S) or transportation stress with flunixin meglumine (SFM).

In Experiment II, AI pregnancy rates were 48, 52, 55, and 62%, for S, CON, SFM, and CONFM treated heifers, respectively (Fig. 3). The FM treated heifers (SFM and CONFM) tended to have higher AI pregnancy rates compared to NFM heifers (S and CON). No differences existed in final pregnancy rates of heifers among treatments. Compared to the pre-treatment blood sample, serum cortisol concentrations

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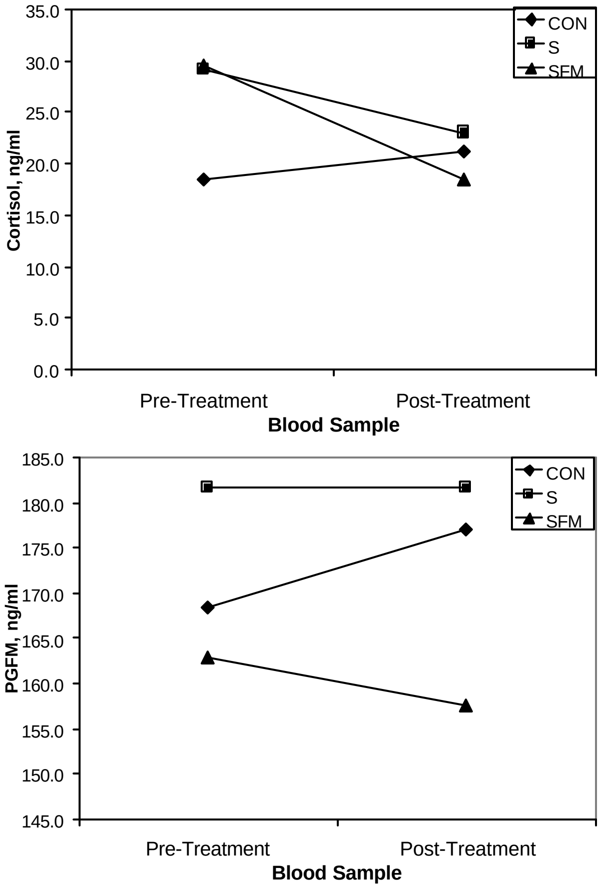

Figure 2. Pre- and post-treatment serum concentrations of cortisol (top panel) and PGFM (lower panel) of control cows (CON) and cows that received 4 hours trucking stress (S) or trucking stress with flunixin meglumine (SFM).

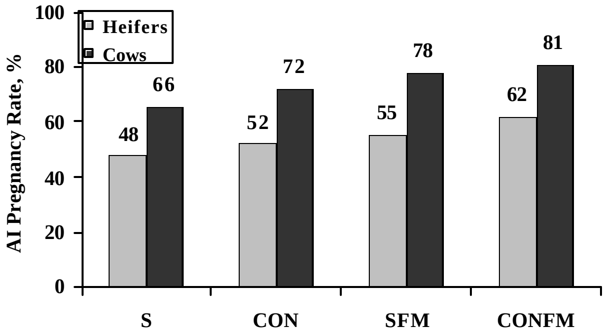

Figure 3. Pregnancy rates following AI in heifers and cows receiving transportation stress (S), control treatment (kept in confinement during transportation of herd mates; CON), transportation stress with Flunixin Meglumine injection (SFM), and Control with Flunixin Meglumine (CONFM) treatments in Exp. 1 and 2.

were elevated 2.5 hours after treatment initiation in transporttation stressed (S and SFM) heifers, but below baseline cortisol concentrations after 5 hours of treatment (Fig. 4). Serum cortisol concentrations did not differ after 2.5 or 5 hours of treatment between CON and CONFM heifers. Serum cortisol concentration of SFM heifers was higher than other heifers after 2.5 hours of treatment. Compared to the pre-treatment blood sample, serum PGFM concentrations decreased after 2.5 hours of treatment for each treatment, but were lower in Flunixin Meglumine treated heifers (SFM and CONFM), and remained lower in these heifers after 5 hours of treatment (Fig. 5).

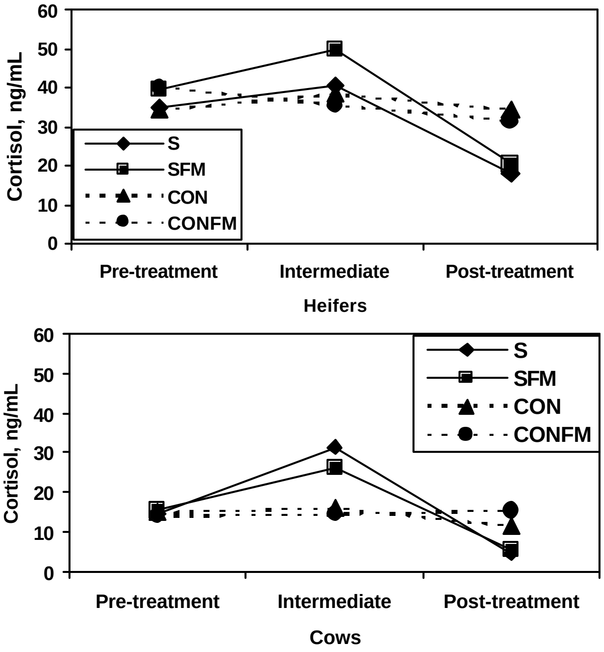

Figure 4. Serum cortisol concentrations of blood samples collected pre-treatment, after approximately 2.5 hours treatment, and post-treatment for heifers in Exp. 2 and cows in Exp. 3 that received transportation stress (S), Flunixin Meglumine + S (SFM), control treatment (CON) or Flunixin Meglumine + CON (CONFM).

In Experiment III, AI pregnancy rates were 66, 72, 78, and 81% for S, CON, SFM, and CONFM treated cows, respectively (Fig. 3). The FM cows (SFM and CONFM) had a higher AI pregnancy rate (80%) compared to NFM cows (66%; S and CON). The magnitude of difference in AI pregnancy rates were similar to those observed in FM and NFM heifers from Exp. 2. Final pregnancy rates of cows were not different. Compared to the pre-treatment blood sample, serum cortisol concentrations were elevated 2.5 hours after treatment initiation in transportation stressed (S and SFM) cows, but below baseline cortisol concentrations after 5 hours of treatment (Fig. 4). Serum cortisol concentrations did not differ after 2.5 hours of treatment between CON and CONFM cows, but were lower in CON cows compared to CONFM cows 5 hours after initiation of treatment. Initial cortisol concentrations of cows were lower than initial cortisol concentrations of heifers. Compared to the pre-treatment blood sample, serum PGFM concentrations decreased after 2.5 hours of treatment for each treatment, but were lower in Flunixin Meglumine treated cows (SFM and CONFM), and remained lower in these cows after 5 hours of treatment (Fig. 5).

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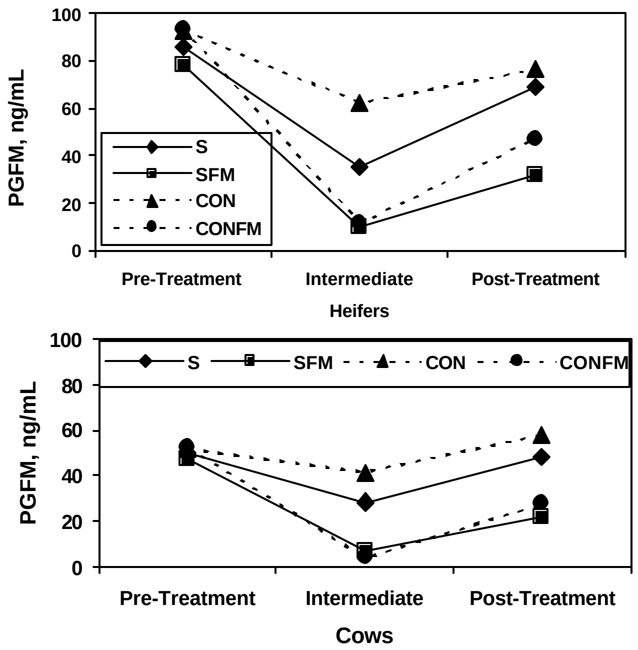

Figure 5. Serum PGFM concentrations of blood samples collected pre-treatment, after approximately 3 hours treatment, and post-treatment for heifers in Exp. 2 and cows in Exp. 3 that received transportation stress (S), Flunixin Meglumine + S (SFM), control treatment (CON) or Flunixin Meglumine + CON (CONFM).

Implications: This study was designed to determine if an injection of flunixin meglumine (0.5 mg/lb) would reduce early embryonic mortality in stressed beef cows. Although there was a trend towards a reduction in embryonic mortality, it would be presumptuous to conclude a positive effect without further studies involving larger numbers of animals and more frequent blood collections to profile hormonal changes. At this time the mechanisms involved are unclear.

Relevant Publications

MERRILL, M.L., R.P. ANSOTEGUI, N.E. WAMSLEY, P.D. BURNS, AND **T.W. GEARY**. 2003. Effects of flunixin meglumine on embryonic loss in stressed beef cows. Proceedings of the Western Section, American Society of Animal Science 54:53-56.

MERRILL, M.L., R.P. ANSOTEGUI, J.A. PATERSON, AND **T.W. GEARY**. 2004. Effect of Flunixin Meglumine on early embryonic mortality in stressed beef females. Proceedings of the Western Section, American Society of Animal Science 55:304-307.

Associations of Growth and Carcass Traits with Attainment of Puberty in Heifers Fed at Two Levels

A.J. ROBERTS, S.I. PAISLEY, T.W. GEARY, E.E. GRINGS, AND M.D. MACNEIL

Problem: Reproductive performance is one of the most important factors influencing level of production and expenses associated with winter-feed are a major factor influencing annual cost of production. Thus, producers are faced with a challenge of optimizing reproductive efficiency while minimizing feed costs. Technical limitations in measuring feed intake by individual animals have limited true measures of feed efficiency. Much of the research in this area has focused on efficiency of converting feed to body weight of growing animals with limited research on level of nutrient intake on milk production in beef cattle. Associations between feed efficiency and reproductive traits have not been explored.

During the past several years there has been increased interest and emphasis on selection for carcass traits. An obvious benefit of this selection approach results from premiums received by producers, either directly or indirectly, for carcass traits. Thus, it is important to establish how selection to improve carcass attributes may affect production characteristics of females retained in the cow herd. Because puberty is the first expressed trait associated with reproduction, and much of the research on feed efficiency to date has focused on the postweaning developmental period, our objectives were to evaluate associations of feed intake, growth, feed efficiency and ultrasound carcass measurements with attainment of puberty in heifers developed under two levels of feeding during a 160-day postweaning study.

Procedures: Heifers used in this study were from the CGC composite herd (½ Red Angus, ¼ Charolais, ¼ Tarentaise). Subsequent to weaning, heifers were randomly assigned to either a control (64 heifers) or restricted (63 heifers) level of feeding. Control heifers were fed to appetite and restricted heifers were fed at 80% of that consumed by controls, adjusted to a common body weight basis. The diet consisted of 67% corn silage, 18% alfalfa, and 15% protein-mineral supplement on a dry matter basis. Heifers were divided into groups of six and each group was placed into one of 22 pens. Each pen was fit with six individual feed bunks equipped with electronic Calan gates to allow for individual feeding. Heifers were allowed approximately one month for adaptation to the pens and diet. Feed restriction was initiated on December 2, 2003 and feeding treatment ended on May 10, 2004 (160 days). Body weight and hip height were measured at the onset of the study and at about one year of age (April 20), after 140 days of feeding. Ultrasound measurements of the ribeye area and ratio (width to height), intramuscular fat (IMF), and subcutaneous fat thickness (FT) were also collected on day 140. After 160 days on the two levels of feeding, heifers were transferred into larger pens for subsequent synchronization of

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estrus and artificial insemination. Gain to feed ratio was calculated for each heifer by dividing weight change during the 140-day period by amount of feed consumed (dry matter basis). Residual feed intake is also a method used to compare efficiency among animals, and is thought to be an estimate of differences in the energy needed by each animal just for maintenance. An average of the on test weight and 140-day weight was calculated for each heifer, and raised to the 0.75 power to provide a midpoint metabolic body weight. Average daily gain (ADG) was calculated for the 140-day period for each heifer. Residual feed intakes were obtained for heifers within feeding treatment using the regression of daily dry matter intake on average midpoint metabolic body weight and ADG for the 140-day period. In simple terms, residual feed intake represents the difference in amount of feed each animal ate after adjusting for differences in animal size and ADG. Residual feed intake values represent the difference of each animal from the average of all animals in each respective feeding group. Residual feed intake values range from negative numbers to positive numbers, representing animals that ate less or more than the average to achieve the same size and ADG.

Serum concentrations of progesterone in blood samples were used to determine percent of heifers that had reached puberty by June 1 (day 180, approximately 13.5 months of age), the date when synchronization of estrus was initiated. Following synchronization of estrus, heifers were subjected to AI and subsequently exposed to bulls for 6 weeks. Bulls were removed from heifers on July 26. Heifers were evaluated for pregnancy by ultrasonography one month later.

Results: Restricted feeding resulted in an average of 3.3 pounds less dry matter of feed intake per day than the control-fed heifers (Table 1). When compared at day 140 of the study, feed restriction resulted in lighter heifers that grew at a slower rate and had smaller, more rounded ribeyes with less fat and marbling than the control heifers (Table 1). However, amount of ribeye per pound of body weight and the hip height of heifers at day 140 (46 inches) did not differ between the two feeding levels. Feed restriction improved the gain-to-feed ratio. Differences observed between levels of feeding are consistent with slower accretion of lean and fat tissue in the restricted group, but no detectable difference in bone growth. The improved gain-to-feed ratio is consistent with lower maintenance requirements of lighter animals, and may also be associated with earlier physiological stages of growth.

Proportion of heifers that were pubertal by day 180 of the study (13.5 months average age) did not differ statistically between restricted (29%) and control heifers (41%). Analyses of growth and carcass trait effects on pubertal status indicated that intramuscular fat, fat thickness, and ADG influenced pubertal status irrespective of feed level. Probability of heifers being pubertal increased with increases in measures of fat (IMF or FT) or ADG. Positive associations among fat deposition and rate of gain with pubertal status are consistent with genetic correlations among these traits reported previously. Collectively, these findings support the concept that traits indicative of early maturation of growth are paralleled by early maturation of the reproductive axis.

Table 1. Effects of feed restriction on feed intake, growth, gain to feed ratio, and ultrasonic measurements of rib eye,, intramuscular fat and fat thickness at day 140 of feeding.

Trait	Restricted	Control	*P* <
Feed intake (lbs dry matter/day)	9.2	12.5	0.001
Body weight at ~ 1 year of age (lbs)	647	711	0.001
Average daily gain (lbs/day)	1.35	1.72	0.001
Gain to feed ratio (lb gained/lb fed)	0.147	0.138	0.045
Rib eye area (in^2)	8.21	9.21	0.001
Rib eye ratio	0.59	0.62	0.002
Intramuscular fat (%)	3.4	3.7	0.006
Fat Thickness (in)	0.16	0.18	0.03

Increases in hip height, body weight and ribeye area at 140 days were each associated with increased chance of control-fed heifers being pubertal, but not restricted heifers. The reason that these traits were associated with pubertal status in control heifers, but not the restricted heifers may be due to the fact that control-fed heifers had greater opportunity to express differences associated with their genetic potential for these traits. Pubertal status did not vary in association with gain-to-feed ratio or residual feed intake. Because neither residual feed intake or gain-to-feed ratio were associated with pubertal status, improved efficiency for maintenance and growth may not be associated with greater partitioning of nutrients for physiological process associated with attainment of puberty.

To provide additional interpretation, predicted values for pubertal status were obtained for the range of each trait analyzed. Values for each trait that resulted in predictions of 25 and 45% of heifers being pubertal are shown in Table 2. This illustrates the relative change for each trait that would be associated with a 20% increase in pubertal status.

Table 2. Values of various traits that result in predicted proportions of pubertal heifers of 25 and 45 percent.

Trait	25 % pubertal	45 % pubertal
Intramuscular fat (%)	3.23	3.99
Subcutaneous fat thickness (in)	0.14	0.21
Average daily gain (lbs/day)	1.3	1.8
[1]Hip height (in)	45	47
[1]Weight (lbs)	668	723
[1]Rib eye area (in^2)	8.3	9.5

[1]These traits were only significant in control fed heifers.

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Pregnancy rates to AI did not differ between the two levels of feeding (60 and 61% for control and restricted heifers, respectively). Likewise, overall pregnancy rates were not different between control (95%) and restricted (90%) heifers.

Implications: Factors that influence age of puberty can have large affects on reproductive success of replacement heifers. Increased propensity for fat deposition and ADG positively influenced attainment of puberty. Potential negative impacts on reproductive performance must be considered if selecting against fat accretion. Variations in efficiency of gain or residual feed intake did not appear to influence attainment of puberty, thus in this population, selecting the more efficient females for replacement would not appear to have negative impacts on puberty. Performance of these heifers as cows is currently under study.

Nutrition Research

Does Dietary Intake Influence Nutrient Utilization in Developing Heifers?

R.C. WATERMAN, E.E. GRINGS, T.W. GEARY,
A.J. ROBERTS, L.J. ALEXANDER, AND M.D. MACNEIL

Problem: One of the major production expenses for cow-calf enterprises is associated with the development of replacement heifers. The present constraints are such that heifers need to obtain 60 to 65% of their mature weight and be pubertal by 14 months of age in order to have their first offspring as 2-year-olds. Typically, for cow-calf producers in the Northern Great Plains this requires providing additional feed resources above that provided by native rangelands from weaning to breeding. Low levels of nutrition following weaning can delay the onset of puberty while high levels of nutrition following weaning may reduce life span and limit milking ability of heifers. Therefore, producers encounter the challenge of first obtaining reproductive competency (puberty) in heifers, and secondly, producers must do so in a cost efficient manner (i.e. minimal feed costs). The objective of the present study was to evaluate the efficiency of nutrient utilization between heifers receiving an ad libitum diet to heifers receiving 20% less adjusted to a common body weight (BW) bases.

Procedures: Sixteen composite gene combination (CGC: ½ Red Angus, ¼ Charolais, ¼ Tarentaise) heifers (8 from each nutritional development program) were randomly assigned to receive a glucose tolerance test (GTT) at the end of the development period. Nutritional program diets contained 67% corn silage, 18% alfalfa hay, and 15% protein-mineral supplement (dry matter basis). The diet was 36.1% dry matter (DM), 15.1% crude protein (CP), 24.6% acid detergent fiber (ADF), and provided 0.71 Mcal/ lb net energy (maintenance) and 0.44 Mcal/ lb net energy (gain). Under the first program (control), heifers were fed to appetite and the second program (restricted) heifers were offered 80% of that consumed by the controls adjusted to a common BW basis with all heifers having ad libitum access to water. For the GTT, a 50% dextrose solution was pulse dosed at a rate of 0.23 mL/ lb body weight. Blood samples were collected at –1, 0, 3, 6, 9, 12, 15, 20, 40, 60, 80, 100, 120, 140, 160 and 180 minutes relative to glucose infusion. Baseline blood glucose, blood urea nitrogen (BUN) and nonesterified fatty acids (NEFA) were analyzed on pre-infusion blood samples (i.e. time -1 and 0). Glucose half-life was estimated for each heifer by regression of the logarithmic-transformed serum glucose concentrations over time. Area under the curve (AUC) was determined for glucose concentrations using the trapezoidal summation method.

Results: Basal blood metabolites were used to describe the nutritional status of heifers receiving both the control and restricted diets at the cessation of the development period. Overall nutrition status for all heifers (control and restricted) was adequate and appeared to meet their metabolic requirements (Table 1). However, BUN concentration, used as an indicator of protein irregularities, provides evidence that protein may have been slightly limiting in both the control and restricted diets. Another possibility, which may explain the relatively low BUN concentrations for the control and restricted heifers, would be the reduced requirement for protein in glucose synthesis (i.e., Gluconeogenesis; the metabolic process of the liver to manufacture blood sugar). Regardless of what may be occurring, the restricted heifers had 19% lower BUN concentrations then those of the control heifers (Table 1). A 23% difference in basal glucose concentrations was also observed between the control and restricted heifers, with the control heifers exhibiting higher glucose concentrations (Table 1). Elevated glucose concentrations were expected since control heifers were receiving nutrients to appetite and receiving an overall high-quality diet. The observed glucose concentrations support the second scenario for BUN, as indicated above, which suggests that when the glucose requirement is satisfied, protein can be partitioned away from a glucose requirement and towards other nutritional needs, such

Table 1. Basal blood metabolites and glucose kinetics following a glucose tolerance test for heifers receiving diets fed to appetite (Control) or heifers offered 80% of that consumed by the controls adjusted to a common BW bases

	Diet			
Item	Control (n=8)	Restricted (n=8)	SEM	*P*- value
Metabolite				
Blood urea nitrogen (mg/100 mL)	4.94	4.00	0.32	0.08
NEFA (µmol/L)	343.13	370.32	37.59	0.64
Glucose tolerance test				
Baseline glucose (mg/ 100 mL)	112.67	86.93	5.76	0.01
Peak glucose (mg/ 100 mL)	234.58	234.44	15.04	0.99
Peak time (minutes)	3.43	2.95	0.29	0.29
Glucose half-life (minutes)	57.51	29.42	5.56	< 0.01
Glucose disappearance (%/minute)	1.17	2.38	0.22	< 0.01
Glucose area under the curve	22620	18310	959.28	0.01

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as lean tissue growth. Additionally, NEFA concentrations were evaluated and used as an indicator of fatty acid mobilization. The basal concentrations of NEFA were within reported normal ranges and indicate that lipogenesis (i.e., synthesis of fatty tissues) may be favorable (Table 1.). The observed blood glucose concentrations also favor fatty tissue synthesis because in the process of breaking down glucose in tissues the required precursors for fatty acid synthesis are generated and basal serum glucose concentrations were sufficient to support this metabolic process. Overall, the basal nutritional status of both the control and restricted heifers seem to be adequate for both lean and fatty tissue growth at the cessation of the development period.

Peak glucose concentrations observed during the GTT indicate that all heifers from both control and restricted groups received the appropriate amount of glucose upon infusion. Likewise, peak concentrations occurred at similar times for both the control and restricted heifers (Table 1). The major difference between control and restricted heifers in response to GTT was how fast glucose was cleared or sequestered out of peripheral circulation and into their tissues. There was a 50% reduction in how fast restricted heifers could incorporate glucose into their tissue (i.e., glucose half-life), which was associated with an increase in glucose disappearance (%/minute) and reduction in total area under the infusion curve (Table 1).

The significance of this initial study suggests that developing heifers with ad libitum access to a high quality diet may not allow proper or efficient utilization of provided nutrients. On the other hand, by restricting heifers or meeting an optimal level of intake of a high quality diet, restricted heifers become more efficient at utilizing dietary nutrients.

Implications: Continued research is warranted in the area of identifying differences in energy utilization during heifer development and following lifetime productivity of heifers developed on both programs. Furthermore, there is a need to determine if efficiencies in nutrient utilization that occur during early heifer development are manifested throughout the cow's life. Current plans include evaluations of heifers used in this study during subsequent parturitions.

Milk Yield of Beef Heifers from Three Calving Systems

E.E. Grings, A.J. Roberts, and T.W. Geary

Problem: Milk yield of the dam is a major determinant of growth rate in beef calves. Forage quality within rangeland systems can affect growth rate of calves through influences on the milk yield of dams and the quality of the forage portion of a calf's diet. Adjusting calving time for beef cows from late winter through late spring impacts the quality of forage available for milk production and growth of calves in the Northern Great Plains. Previous research at this location has shown decreased weaning weights in calves from Late Spring compared to Late Winter and Early Spring systems. This study evaluated the milk yield of first-calf heifers born and raised within three calving systems and the impact on growth of their calves.

Table 1. Least squares means of total milk yield, yield at peak lactation, day of peak lactation, and calf ADG measured in 2002 and 2003 for first-calf heifers from three calving systems.

	Calving system		
	Late Winter	Early Spring	Late Spring
Total yield (lbs)			
2002	2407 b[1] A[2]	2319 b A	2727 a A
2003	2676 a A	2557 a A	1976 b B
Yield at peak (lbs)			
2002	18.3 b A	18.3 b B	24.9 a A
2003	18.3 a A	20.9 a A	20.3 a B
Day of peak	88 a	61 b	51 b
Calf ADG (lbs/day)			
2002	2.09 a B	1.94 b B	2.00 ab A
2003	2.22 a A	2.09 ab A	1.56 b B

[1] Means within a year and measurement followed by the same lower case letter do not differ.

[2] Means within a calving system and measurement followed by the same upper case letter do not differ.

Procedures: *Herd Management:* In a 2-year study, first-calf heifers from three calving systems were used to study milk yield throughout a 190-day lactation. Heifers and their calves were from the same calving system, with calving dates of late January to late February (Late Winter calving), mid-March to mid-April (Early Spring calving), and mid-May to mid-June (Late Spring calving). First-calf heifers were sired predominately by composite bulls (½ Red Angus, ¼ Charolais, ¼ Tarentaise) with dams being crossbred cows of varied genetic background, including some combinations of Hereford, Limousin, Charolais, and composite breeding. In 2002, calves were sired by bulls that were at least ¼ composite breeding, whereas in 2003 calves were sired by Angus bulls. Breeding was from about April 6 to May 9, June 6 to July 9, and August 6 to September 9 (exact dates vary by year). Each calving herd was managed separately throughout the year, with inputs appropriate for the specific calving season. Quantity and quality of hay and supplements were provided based upon forage and weather conditions, physiological state of the cows, and available harvested feed resources within a year. During the period of milk production measurements heifers were maintained primarily on native rangeland. However, supplemental feed was provided to Late Winter heifers through the third milk yield measurement and to the Early

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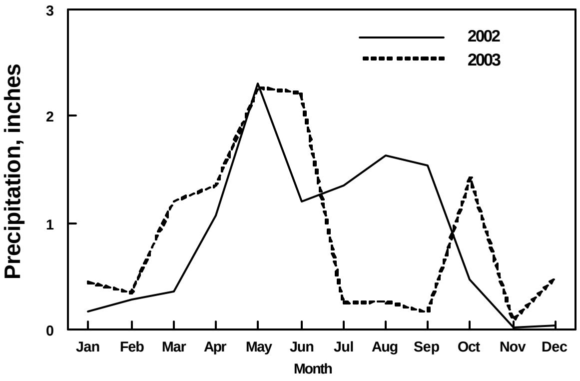

Figure 1. Precipitation during 2002 and 2003 at Miles City, MT (NOAA 2002, 2003).

Spring heifers through the first milk yield measurement. No supplemental feed was provided to the Late Spring heifers during lactation.

Animal Data Collection: Milk production was measured by weigh-suckle-weigh technique. Average days in milk at yield measures were 20, 38, 55, 88, 125, 163 and 190 days. Calves were separated from their dams for 8 hours, allowed to suckle until full, and separated again for 12 hours. Calves were then weighed, allowed to suckle until full and re-weighed. Milk yield was calculated as the difference between the pre- and post-suckling weight. Milk yield was multiplied by two to obtain 24-hour milk production estimates for calculation of total yield. Milk yield for the entire lactation period was calculated as area under the curve by trapezoidal summation.

Diet Quality: Diet quality during grazing periods was estimated from esophageal extrusa. Extrusa samples were collected within a week of milk yield measures for each herd.

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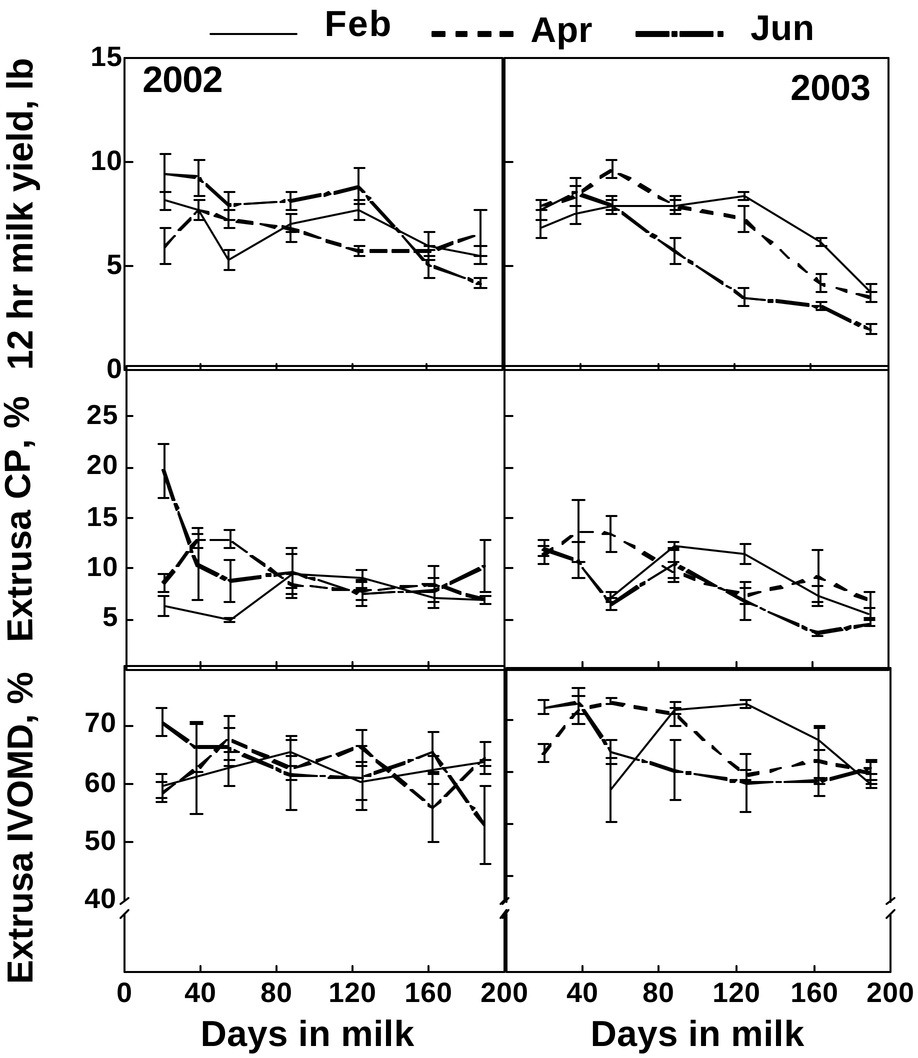

Figure 2. Twelve-hour milk yield, extrusa %CP and IVOMD ± standard error in 2002 and 2003 for heifers from 3 calving systems (Feb, Apr, Jun). In addition to range forage, supplemental feed was provided to Feb heifers through the third milk yield measurement and to the Apr heifers through the first milk yield measurement. Supplemental feed was not provided to the Jun heifers during lactation. No diet samples were collected for the Feb calving system at the second milk yield period in 2002 or the first and second milk yield periods of 2003 because snow cover precluded grazing.

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Extrusa samples were analyzed for dry matter, ash, crude protein, and in vitro organic matter digestibility. Extrusa samples were not collected at the second milk yield period in 2002 or the first and second milk yield periods for 2003 for the Late Winter calving system because snow cover precluded grazing at that time.

Results: Precipitation patterns differed between the two years of the study (Fig. 1), resulting in varied extrusa quality between years. Although year effects were not significant for milk and calf gain measures, there were calving system-by-year interactions for all measures except day of peak lactation.

Total milk yield did not differ between heifers in Late Winter and Early Spring systems, yet both differed from Late Spring. However, this relationship was affected by year. In 2002, Late Spring heifers produced more, whereas in 2003 they produced less milk than heifers in other calving systems.

While yield for heifers in the Early Spring system did not differ between years, it varied between years for both the Late Winter and Late Spring systems. Heifers in the Late Winter system produced more milk in 2003 than in 2002, whereas the opposite was true for the Late Spring heifers. The lowered milk yield in 2003 for the Late Spring heifers is related to the lowered extrusa quality observed in that year (Fig. 2). The extrusa quality curves observed for 2003 may be the more typical for this Northern Great Plains environment.

The average daily gain of calves for the three systems related well to the total milk yields. Late Winter calves showed an increased rate of gain in 2003 compared to 2002 and Late Spring calves grew more slowly in 2003 than 2002, both relationships following the trend in milk yield. Calves in the Early Spring system grew faster in 2003 compared to 2002. Milk yield was numerically, but not statistically greater for the Early Spring heifers in 2003 compared to 2002.

Milk yield at peak lactation was affected by calving system with the relationship differing between years. In 2002, peak milk yield did not differ between Late Winter and Early Spring heifers and both were less than Late Spring heifers. In 2003 peak milk yield in Early Spring and Late Spring heifers did not differ and both were greater than Late Winter heifers.

Day of peak lactation differed among calving systems with heifers in the Late Winter system peaking later than those heifers from other systems. Average calendar day of peak lactation was May 4 for the Late Winter system, May 31 for the Early Spring system, and July 19 for the Late Spring system. Day of peak did not differ among years even though extrusa quality patterns differed between years.

Proportion of heifers pregnant was not affected by calving system or year. Proportion of heifers pregnant averaged 0.81 (± 0.06) for Late Winter, 0.89 (± 0.05) for Early Spring, and 0.82 (± 0.06) for Late Spring calving systems.

Implications: Season of calving and its associated management affects time and amount of milk yield in heifers, corresponding to varied weight gains in their calves. Understanding the impacts of calving date on amounts and patterns of milk production can aid in developing management systems to best match nutrient needs of cow-calf pairs in different calving systems.

Post-Weaning Production of Steers from Varying Calving and Weaning Strategies

E.E. GRINGS, R.E. SHORT, AND R.K. HEITSCHMIDT

Problem: Calves from various calving seasons and weaning strategies may differ in weight at weaning in rangeland-based production systems. Profitability of post-weaning production of steer calves from differing systems could then be influenced by the length of time in the feedlot and, potentially, carcass composition. This study was conducted to determine the post-weaning production characteristics of steers from various beef production systems in the Northern Great Plains.

Procedures: Three calving seasons produced 215 steers. Calving seasons were Late Winter (average=Feb 8), Early Spring (average=Apr 5), and Late Spring (average=May 31), created by 32-day breeding seasons with no overlap between seasons. Crossbred cows were bred by natural service to bulls from a composite herd (½ Red Angus, ¼ Tarentaise, and ¼ Charolais). Each calving season had two weaning times: 6 or 8 months of age for Late Winter and Early Spring steers, or 4 or 6 months of age for Late Spring steers. Before weaning, cow-calf pairs grazed native rangeland with supplemental feed as needed. Later weaned cow-calf pairs continued to graze native range until weaning. Calves received pre-weaning vaccines about 3 weeks before weaning with boosters at weaning.

At weaning, steers were immediately transported to feeding facilities (within 5 miles) and received long-stemmed hay for a few days followed by a corn silage-based diet for about 3 weeks. Steers were then weighed early in the morning about 24 hours after feeding. Steers were sorted into three treatment groups per calving season with one pen per treatment-calving season combination. Results of only one post-weaning treatment will be reported here. Calves from the later weaning within a calving season were penned with the earlier weaned steers when they were placed on treatment. Steers did not receive any implants during their lifetime. Steers were penfed a corn silage-based diet (Table 1) until the weaning group averaged 826 lbs. They were then moved to an individual feeding facility for recording of daily feed intake and trained to work electronic head gates. Once the group reached an average of 890 lbs, they were shifted to a diet of higher energy concentration (Table 1). Steers were allotted to harvest dates based upon visual estimates of fat thickness. Steers were sent to a local abattoir for harvest then carcass characteristics were measured.

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Results: Weights of steers at the start of the study were affected by calving season and weaning age (Table 2). Late Spring steers weaned at 4 months of age were lighter than other steers. Late Spring steers weaned at 6-months of age weighed 53 lbs less than the average of the Late Winter and Early Spring steers weaned at a similar age.

Table 1. Ingredient and chemical composition of diets fed to steers during growing and finishing phases.

	Growing	Finishing
Ingredient	------% of dry matter-------	
Corn silage	62.5	16.5
Rolled barley	19.4	39.5
Cracked corn	N/A	40.7
Alfalfa hay	14.8	N/A
Soybean meal	2.3	1.3
Limestone	0.3	1.4
Urea	0.5	0.3
Salt	0.1	0.2
Trace mineral mix	0.03	0.04
Vitamin A,D,E	0.04	0.04
Chemical		
Dry matter (%)	39.8	65.5
Crude protein (% dry matter)	11.7	10.8
Acid detergent fiber (% dry matter)	25.7	12.3
Net energy, maintenance (Mcal/lb dry matter)	0.75	0.89
Net energy, gain (Mcal/lb dry matter)	0.47	0.59

No treatment differences in average daily gain were observed during the growing or finishing phases (Table 2). Feed efficiency during the finishing period was greater for the Late Winter compared to the Late Spring steers when weaned at 6 months of age. Feed efficiency during the growing phase was not measured.

Total days to harvest are artificially elevated in this study because of the time required to adapt steers to electronic head gates between the growing and finishing periods. Steers from the Late Winter calving systems that were weaned at 6 months of age required an extra 43 days in the feedlot compared to those weaned at 8 months of age. Days to harvest were not different between Early Spring steers weaned at the two ages or Late Spring steers weaned at 4 or 6 months of age. Age at harvest was less for Late Spring steers weaned at 4 months of age than for Late Spring steers weaned at 6 months of age and Late Winter steers weaned at 8 months of age.

Steers from the Late Winter calving systems that were weaned at 6 months of age were heavier at harvest than Early Spring, but not Late Spring steers weaned at the same age (Table 3). Hot carcass weights were heavier for Late Winter steers weaned at 6 months of age than Early Spring and Late Spring steers weaned at the same age. Steers from the Late Winter and Early Spring calving systems that were weaned at 8 months of age did not differ in either harvest or hot carcass weights.

We attempted to harvest all groups at a similar fat thickness (0.4 inches). However, steers from the Late Winter calving system that were weaned at 6 months of age had greater fat thickness than steers from the Late Spring calving system. Carcass data reported here is adjusted to an equivalent fat thickness. Ribeye area was greater for the Late Winter steers weaned at 8 months of age than both the Late Winter steers weaned at 6 months and Late Spring steers weaned at 4 months of age. Marbling score was greater for both groups of Late Winter steers compared to Early Spring steers weaned at

Table 2. Body weight, average daily gain, days on feed and feed efficiency during the growing and finishing periods of steers born in Late Winter, Early Spring, or Late Spring and weaned at two ages.

Calving season:	------ Late Winter ------		------ Early Spring ------		------- Late Spring -------	
Weaning age:	6-month	8-month	6-month	8-month	4-month	6-month
On test weight (lbs)	534 b	598 a	523 b	576 ab	418 d	475 c
Grower average daily gain (lbs/day)	2.31	2.39	2.28	2.47	2.25	2.38
Days on growing diet	168 bc	112 c	153 bc	155 bc	235 a	195 ab
Days on finishing diet	123 a	117 ab	86 c	96 bc	92 bc	116 ab
Total days to harvest	304 a	261 b	283 ab	252 b	332 a	312 a
Age at harvest (days)	499 ab	515 a	488 ab	505 ab	476 b	511 a
Gain to feed, finishing phase (lb gain/lb dry matter)	0.17 a	0.16 ab	0.16 ab	0.15 ab	0.17 ab	0.15 b

abc Means followed by the same letter do not differ.

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Table 3. Harvest weight and carcass characteristics of steers born in Late Winter, Early Spring, or Late Spring and weaned at two ages. All results except fat thickness are corrected to an equivalent fat thickness. The intended harvest endpoint was 0.4 inches of back fat.

Calving Season:	------ Late Winter ------		------ Early Spring ------		------ Late Spring ------	
Weaning Age:	6-month	8-month	6-month	8-month	4-month	6-month
Harvest weight (lbs)	1238 a	1189 ab	1150 b	1174 ab	1160 b	1171 ab
Hot Carcass weight (lbs)	725 a	702 ab	666 c	684 bc	664 c	680 bc
Fat thickness (in)	0.45 a	0.39 ab	0.40 ab	0.37 ab	0.33 b	0.36 b
Ribeye area (in^2)	12.4 ab	12.6 a	12.0 b	12.3 ab	11.9b	12.2 ab
Marbling score [d]	503 a	497 a	456 ab	426 b	412 b	454 ab
Kidney , pelvic, heart fat (%)	2.9 ab	2.8 ab	3.0 a	2.8 ab	2.8 ab	2.7 b
Yield grade	2.86 a	2.65 b	2.74 ab	2.69b	2.70 ab	2.65 b
Quality grade [e]	12.6 a	12.6 a	12.4 ab	11.9 b	11.8 b	12.3 ab

[abc] Means followed by the same letter do not differ.
[d] Practically devoid = 100-199, traces = 200 to 299, slight = 300 to 399, small = 400 to 499, modest = 500 to 599, moderate = 600 to 699.
[e] Prime+ = 17 , Prime = 16 , Prime - = 15, Choice + = 14, Choice = 13, Choice - = 12, select = 11 standard = 10.

8 months of age and Late Spring steers weaned at 4 months of age. Percentage of kidney, pelvic and heart fat was greater in Early Spring steers weaned at 6 months of age compared to Late Spring steers weaned at the same age. Yield grade was greater in Late Winter steers weaned at 6 months of age than either Late Winter or Early Spring steers weaned at 8 months of age and Late Spring steers weaned at 6 months of age. Quality grade was higher for Late Winter steers weaned at 8 months of age than Early Spring and Late Spring steers weaned at 8 and 4 months of age.

Implications: Season of birth can impact growth and carcass composition, independent of steer age at weaning when harvested at equivalent fat thickness. This may be related to environmental factors, both during the feeding period and before weaning. Calving season should, therefore, be considered in effective feedlot management strategies along with weaning age and weight at feedlot entry.

Season of Calving, Weaning Strategies, and Retained Ownership Effects on Economic Profitability

R.E. KRUSE, E.E. GRINGS, W.A. PHILLIPS,
AND M.W. TESS

Problem: In cow-calf beef production systems, management decisions are driven by possible economic outcomes, which are based on cow-calf performance and input costs. Research in many regions of the US has shown that feed costs are often the largest portion of input costs in production systems. This research was conducted to identify calving seasons and strategies of weaning and marketing that match the animals' nutrient needs, reduce input costs, and optimize economic outcomes. The data reported here include economic results for simulated cow-calf beef production systems utilizing different seasons of calving, weaning strategies, and retained ownership options.

Procedures: This research evaluated the impact of season of calving, weaning strategy, and retained ownership of steer calves on production system profitability by utilizing data collected during a 3-year study and modeling the economic performance of beef cattle production systems through the backgrounding phase. Animal performance and feed input data were collected from three cow herds observed from 1998-2001 and with differing calving seasons; late winter (February), early spring (April), and late spring (June). February and April calves were weaned at 6 and 8 months of age; June calves were weaned at 4 and 6 months of age. Each calving season was managed separately and there were no differences in management for cows assigned to each weaning strategy within calving season except time of weaning. Tables 1 and 2 present economic inputs including marketing, animal, and feed costs for the cow-calf systems. After weaning, all steers were placed into one of three retained ownership options, 1) backgrounded in El Reno, OK on forage based diets, 2) backgrounded in Miles City, MT on a corn silage-hay diet, and 3) backgrounded in Miles City, MT on a corn silage-hay-barley diet. Table 3 presents feed costs for the backgrounding systems

Production systems were developed to characterize each possible combination of factors. The April late weaned system was used as the base system as it best characterizes what traditionally occurs in the Northern Great Plains. The fixed amount of land for the base system was set by using the forage intake per animal and applying that to a 500-cow herd. Each subsequent system deviated in the number of cows from the

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base system as the amount of grazing time differed between systems. Forage intake per animal was determined by using the MSU beef production system model that was parameterized to be consistent with the cattle performance for each specified management scenario. Economic performance of each system was based on animal performance and variable input costs. Point estimates of animal performance were used regardless of statistical significance. Monthly feeder cattle prices were based upon the Billings, MT cattle market. Actual prices for feed were used where available. Economic measures reported here include ranch gross margin (RGM = gross revenue minus variable costs) for cow-calf systems and cumulative gross margin (CGM = RGM plus gross revenue from backgrounding minus variable costs) for systems utilizing the backgrounding phase.

Table 1. General expenses for all cow-calf systems.

Item	Value
Marketing	
Brand inspection and checkoff ($/animal)	1.30
Pencil shrink on calves (%)	2
Actual shrink on yearlings and cows (%)	4
Commission, culls only (%)	2.5
Annual expenses[a] ($/animal)	
Steer calves	11.56
Heifer calves	11.56
Yearling heifers	46.23
Two-year-old cows	50.57
Mature cows	51.18
Bulls	579.53
Interest on variable expenses, %	10

[a] Include vaccinations, property taxes, opportunity cost of investment (5% for yearlings and older), miscellaneous health treatments, ear tags, and depreciation ($427, bulls only).

Results: June calves were lighter at weaning than February and April calves. These results are similar to other research, where weaning weight decreased as calving season advanced. However, our results show that for cow-calf production systems selling calves at weaning, June systems yielded higher RGM than all other systems (Fig. 1). This was primarily due to the increase in feed costs for systems calving in February and April (Table 2).

When steer calves were backgrounded after weaning, systems utilizing June calving yielded higher gross margin than those utilizing February or April (Fig. 2). Although there were differences in feed and transportation costs (data not shown) among backgrounding options, there were no differences in CGM among backgrounding options within calving season. This was primarily due to differences in the cost of weight gained by steers in the backgrounding phase and timing of

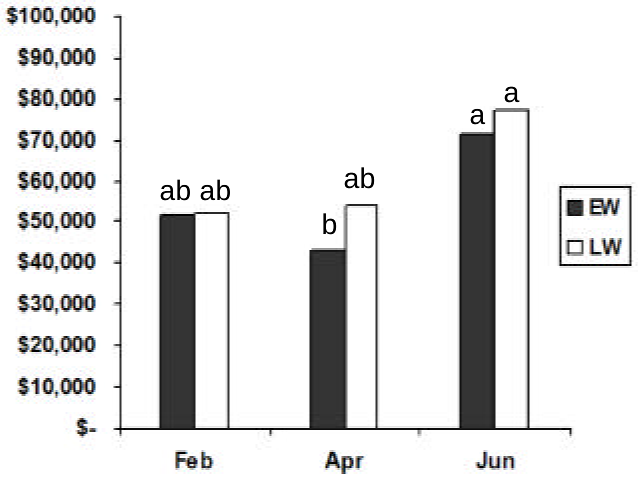

Figure 1. Average ranch gross margin for cow-calf systems utilizing three seasons of calving (Feb, Apr, Jun) and two weaning strategies (early and late weaning).

Table 2. Feed costs, morbidity, calf mortality, and calf weaned per cow calving by calving season for cow-calf systems.

	Feb	Apr	Jun
Feed ($/animal)			
1998-1999	149.23	97.72	87.93
1999-2000	75.71	106.87	0.00
2000-2001	216.13	278.73	122.00
Morbidity (%)	6	2	2
Calf mortality (%)	3.5	1.5	1.5
Calf weaned per cow calving, CWCC (%)	96	98	98

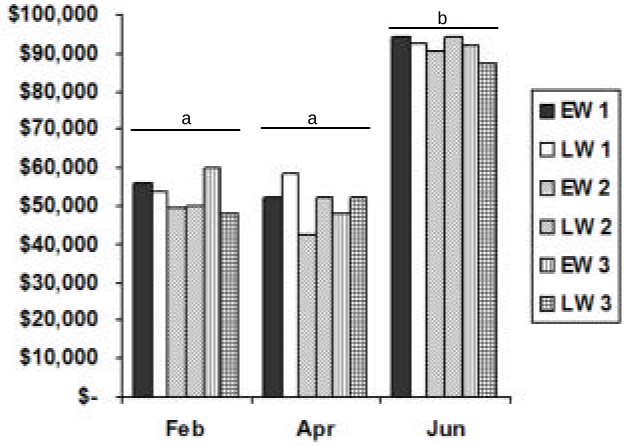

Figure 2. Average cumulative gross margin for backgrounding systems utilizing three backgrounding treatments (1, backgrounded in El Reno, OK; 2, backgrounded in Miles City, MT and fed similarly to those in El Reno; 3, backgrounded in Miles City, MT) within calving season and weaning strategies.

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Table 3. Yearly feed costs by calving season (Feb, Apr, or Jun) and weaning age (4, 6, or 8 months for early [EW] or late [LW] weaning) for backgrounding systems.

	February Calving		April Calving		June Calving	
	Age at Weaning					
	6 Months	8 Months	6 Months	8 Months	4 Months	6 Months
Treatment 1	Yearly feed cost ($/animal)					
1999	87.59	69.62	68.03	67.32	61.33	68.29
2000	161.06	150.21	107.09	N/A	109.20	n/a
2001	94.99	69.83	73.21	62.84	61.60	71.23
Treatment 2						
1999	203.80	176.16	147.76	131.73	124.57	118.02
2000	212.42	192.72	160.78	142.36	147.39	124.97
2001	153.77	125.12	164.78	128.66	128.87	119.47
Treatment 3						
1999	136.23	113.90	134.37	118.47	137.90	131.18
2000	143.34	125.32	149.84	157.31	157.36	156.10
2001	162.00	161.08	153.62	115.99	165.08	150.76

sale. June steers gained a large amount of weight compared with February and April steers (data not shown) in backgrounding treatments 1 and 2. In treatment 3, June steers were not sold on a time basis but on weight and were sold at a favorable time.

Implications: Many cow-calf producers consider changes in calving season either to increase fall calf weights or to more closely match nutrient requirements to the available forage quality. For producers managing ranches in the Northern Great Plains similarly to these systems, June calving offers promise as a means to increase profit. The benefits of reducing input costs exceeded income lost due to the reduction in weaning weights through backgrounding.

Rangeland Research

Predicting Forage Quality in the Northern Mixed-Grass Prairie

M.R. Haferkamp, M.D. MacNeil, and E.E. Grings

Problem: Quantity and quality of forage are important factors affecting livestock production from grazing lands. Providing managers with methods to evaluate forage quality would allow more cost-effective utilization of resources.

A model predicting forage quality from easily measured variables, such as daily temperatures and relative greenness of forage would aid livestock producers in developing nutritional tactics relative to current forage conditions. The objective of this research was to assess the potential for estimating nitrogen (N) content of rangeland forage using dead-to-green ratio and accumulated growing-degree days (DD).

Procedures: The 2.5-acre base-line study site was a nearly level silty range site at Fort Keogh. Soil was an Eapa fine-loam. Perennial cool-season grasses and sedges generally made up greater than 60% of the green forage during April through July each year. Perennial warm-season grasses and sageworts became more obvious during July.

Temperature records were obtained from a weather station located at Frank Wiley Field, 7.8 miles from the study site. Growing-degree days for base temperature 45°F were calculated and accumulated from April through October each year (Table 1).

Forage samples used to develop the regression equation in the base-line study came from an experiment conducted during 1996, 1997, and 1998. Three treatments were imposed on replicated plots: no grazing, intensive grazing by sheep in mid-May, and intensive grazing by sheep in mid-July (July). Grazing reduced the amount of live forage by 68 to 78% during both May and July. Current standing dead (i.e., this year's senesced forage) was similar before and after grazing in May, but was reduced 56 to 71% by grazing in July. Old standing dead was reduced 65% when averaged across years.

Table 1. Accumulated growing degree days for base temperature 45°F derived for 1996-1998 for Miles City, Mont.

Month	1996	1997	1998
	------------- Growing-degree days -------------		
April	42	0	183
May	244	366	620
June	952	1155	1082
July	1817	2014	2111
August	2769	2894	3106
September	3213	3533	3838
October	3253	3673	3971

Forage samples were collected from mid-April to mid-October at 30-day intervals each year. On each sample date, forage was clipped to ground level and sorted into live, current standing dead, and old standing dead tissue. Samples were oven-dried, ground, and analyzed for total N.

The relationship of %N with DD and percent dead (NL) was quantified using multiple regression. The predictive equation was validated using data for April through September from an independent study conducted on 8 silty and claypan range sites. Forage samples from these sites had been separated into live and dead components, and %N was determined.

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Table 2. Mean %N in total above-ground forage for the significant month within year by treatment interaction. Standard error of the mean = 0.08. Data from samples collected in a study during 1996-1998.

Year/treatment	April	May	June	July	August	September	October
1996	(% N)						
Control	N/A	1.73	1.38	1.00	0.86	0.73	0.75
May grazed	N/A	N/A	1.47	1.15	0.89	0.67	0.80
July grazed	N/A	N/A	N/A	N/A	0.87	0.62	0.93
1997							
Control	1.02	1.23	1.16	1.10	0.87	0.86	0.88
May grazed	1.23	1.39	1.60	1.32	1.06	0.87	0.91
July grazed	1.43	1.70	1.33	1.11	0.98	0.95	0.76
1998							
Control	1.22	1.42	1.13	1.27	1.20	1.18	0.92
May grazed	1.32	1.54	1.33	1.62	1.41	1.19	1.07
July grazed	1.94	1.72	1.18	1.34	1.23	1.15	1.22

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Results: Grazing treatments applied in this study and the dynamic environmental conditions encountered during the 3 years provided a wide range in production and quality of forage. Standing forage across years and treatments was 589 lbs/acre for total, 259 lbs/acre for live, 134 lbs/acre for current dead, and 188 lbs/acre for old dead. Depending on the year, percent live peaked in May, June, or July. Percent current dead + old dead was greatest in spring and autumn. Percent current dead increased as the growing season progressed, whereas the old dead was greatest in spring and gradually decreased through time.

Forage N was greatest in spring and early summer and decreased as plants matured and environmental stress increased (Table 2). The slightly higher spring forage N values in May- and July-grazed plots compared to controls reflect reduction in the old dead component by grazing and perhaps trampling. Regrowth of May-grazed plots generally provided greater %N in June and July compared to controls and July-grazed plots.

Equation Development and Validation: In the base-line study, total forage sample N averaged 1.17%, accumulated DD averaged 2127, and dead averaged 57.1%.

The final model was:

$$\%N = 2.215 - (507DD + 0.18DD^2 - 563NL - 93.68NL^2 - 5.52DDNL + 0.0013\,DD^2NL + 0.095DDNL^2) \div 1{,}000{,}000$$

Where:
%N is N content of forage on a given date;
2.215 is the intercept of the regression equation (predicted %N if degree day and percent dead were both zero);
DD is the growing degree days accumulated to that date in the year and;
NL is the percent dead plant material.

All independent variables contained in the equation, except the linear effect of percent dead, were significant. Individually, the independent variables explained 3% or less of the variation in %N. However, collectively the model accounted for 75.9% of variation in %N, and the prediction error variance was 0.026. The seeming disparity between variation accounted for by each of the independent variables and the model results from colinearity among independent variables.

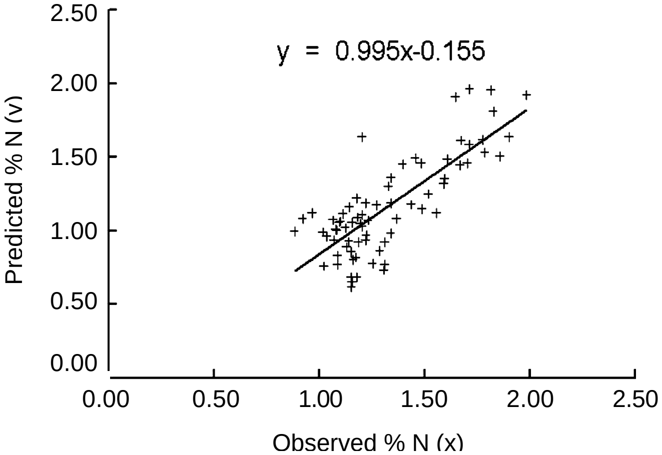

Figure 1. Relationship of predicted to observed %N from the validation study.

When this equation was used to predict %N in the validation study samples, the correlation of predicted and actual values was 0.79 and prediction error variance was 0.042. On average, a 1% change in observed %N was associated with a 1% change in %N predicted using this equation (Fig. 1).

Implications: Rangeland forage resources used in this research were heterogeneous with respect to species composition. Variation among individual species in morphological development and senescence with respect to accumulated DD was anticipated. Additionally, the relationship between forage quality and time has been shown to be non-linear across a growing season. These factors likely contribute to the significance of quadratic and interaction terms in the prediction of % N.

This procedure could easily be conducted by a single individual. Temperature information needed to calculate DD can be obtained by the use of a maximum-minimum thermometer or access to on-line weather information. Other supplies needed would include scissors or gardening shears for clipping and a small scale, such as a kitchen scale, for weighing live and dead components. Samples could be air-dried or dried in ovens. Percent N can be calculated from the regression equation using a programmable hand calculator or computer spread sheet.

Development of a Proactive Drought Management Tool

R.K. HEITSCHMIDT, R.E. KRUSE, L.T. VERMEIRE,
AND M.W. TESS

Problem: A fundamental problem in rangeland is that too often management's response to a drought situation is reactive rather than proactive (i.e., no management actions are implemented until the forage base is fully depleted). Although there are many reasons for this, probably the biggest reason is that most ranchers are eternal optimists when it comes to precipitation. Their everyday mindset is: "we are one day closer to the next rain, so let's not panic and do anything rash." Granted, for sanity's sake, this mindset is somewhat a must for ranchers, otherwise they would most likely not have a very enjoyable life. But there is another component to this problem that needs addressing, and that is ranchers have seldom if ever been provided a drought management scheme they feel comfortable using, that is, something they have confidence in. The objective of this research is to develop an effective, proactive, easy to use, drought management tool.

Procedures: Research has been conducted in a step-wise sequence. First, using herbage production, precipitation, and temperature data from Fort Keogh and near Lethbridge, Alberta, Canada, we simulated herbage production using a simulation model called Rangetek which is a modification of the ERHYM -II model. Second, we used this model to evaluate the relationships between monthly precipitation, temperature, and annual forage production. Third, we examined among months the relationships between above-, average, and below-average precipitation at Fort Keogh and Miles City. Data used were monthly precipitation values for the past 106 years. Fourth, we examined the seasonality of perennial grass production at Fort Keogh using 13 different data sets collected over the past 14 years. Finally, we incorporated monthly rainfall probabilities into our decision support system using data from the High Plains Regional Climate Center at the University of Nebraska in Lincoln, NE (http://hprcc.unl.edu/index.html).

Results: Based on successfully simulating herbage production at Fort Keogh, we found a strong correlation between April and May precipitation and annual herbage production, with amount of precipitation in each month explaining about 30% of the variation in herbage production among years. These estimates were further refined by adding previous October and November precipitation, so much so that we could explain about 84% of the variation in forage production among years.

From an examination of monthly precipitation values at Miles City over the past 106 years, we found no relationships among months. In other words, knowing it is dry, average, or wet in any given month provides no information about what precipitation will be in any other month. Quite simply, we cannot predict whether a given month's precipitation will be below-average, average, or above-average based on any other month's relative precipitation.

Analyses of the timing of perennial grass production at Fort Keogh revealed that on the average, 35, 69, and 91% was produced by May 1, June 1, and July 1, respectively. More detailed analyses showed that we can be 95% confident (i.e., 19 out of 20 years) that at least 67% of our perennial grass forage will be produced by July 1 with greater than 90% produced in a majority of the years. Estimates were slightly greater for cool-season perennial grasses and substantially lower for warm-season perennial grasses, but because of the overwhelming dominance of cool-season species in this region, estimates for total perennial grass production were near that for cool-season perennial grass production.

We then coupled the above information to the precipitation probability estimates derived from the High Plains Regional Climate Center. For example, we can see that there is about an 85% chance that Miles City will receive 1 inch of precipitation in June, about a 40% of receiving 1 inch in either July or August (Fig. 1). And we can see that these probabilities drop off dramatically in terms of probability of receiving 2 inches of precipitation (Fig. 2).

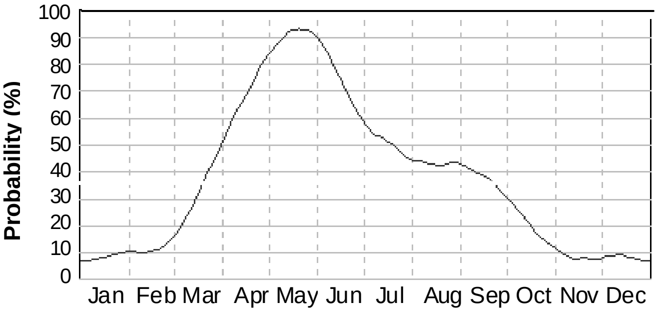

Figure 1. Probability of receiving 1 inch of precipitation at Wiley Field Airport in Miles City during a 30-day period, beginning with the date selected. Data from http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mtmile.

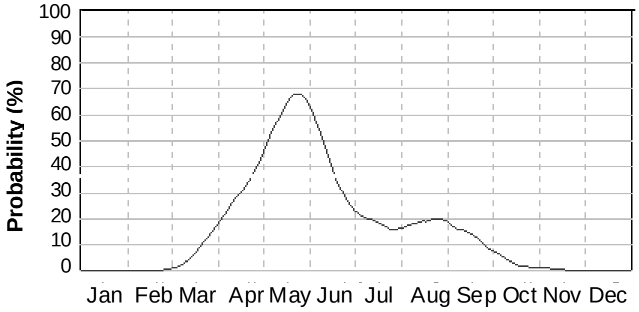

Figure 2. Probability of receiving 2 inches of precipitation at Wiley Field Airport in Miles City during a 30-day period, beginning with the date selected. Data from http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mtmile.

We intend to continue exploring the utility of this very effective, yet simple drought management decision support system, across the Northern Great Plains. We also plan to experimentally determine the effects of substantial July and August rain and how much effect it has in terms of growing forage.

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Implications: These data strongly suggest that ranchers in this region can determine, with considerable confidence, their herbage situation for the current summer, next fall and winter by early July because: 1) herbage production is largely a function of previous fall and current spring precipitation; and 2) the probability of getting substantial growing season precipitation after July 1 is low.

Related Publications

Heitschmidt, R.K., E.E. Grings, M.R. Haferkamp, and M.G. Karl. 1995. Herbage dynamics on two Northern Great Plains range sites. Journal of Range Management 48:211-217.

Heitschmidt, R.K., M.R. Haferkamp, M.G. Karl, and A.L. Hild. 1999. Drought and grazing: I. Effects on quantity of forage produced. Journal of Range Management 52:440-446.

Heitschmidt, R.K. and M.R. Haferkamp. 2003. Ecological consequences of drought and grazing on grasslands of the Northern Great Plains. p. 107-126. In: J.F. Weltzin and G.R. McPhearson (eds.) Changing precipitation regimes and terrestrial ecosystems. The University of Arizona Press.

Heitschmidt, R.K., K.D. Klement, **and M.R. Haferkamp.** 2005. Interaction effects of drought and grazing on Northern Great Plains rangelands. Rangeland Ecology & Management 58:11-19.

Kruse, R.E., M.W. Tess, **R.K. Heitschmidt**, J.A. Paterson, and K.D. Klement. 2002. Evaluation of drought management strategies for cow-calf enterprises. A practical predictor of growing season forage production. Proceedings of the Western Section, American Society of Animal Science 53:212-215.

Why Can't We Grow Forage in July and August?

R.K. Heitschmidt, L.T. Vermeire,
and M.R. Haferkamp

Problem: Elsewhere in this Research Update, we report that about 90% of our rangeland forage is grown in this region by July 1. We hypothesized that the reason for this was largely because of the limited amount of precipitation we receive after July 1. The question then becomes – how much forage could we grow if we received substantial precipitation during July and August?

Procedures: During the 2005 growing season, we established 4, thrice-replicated precipitation treatments using a combination of rainout shelter technology and irrigation. Treatments were: 1) drought from April 1 to July 1 with ambient precipitation thereafter (hereafter referred to as the DNI treatment where D=drought, N=no, and I=irrigation); 2) drought from April 1 to July 1 and ambient conditions thereafter with 3 inches of irrigation water added in both July and August (DI); 3) ambient conditions throughout the year (NDNI); and 4) ambient conditions throughout the year plus 3 inches of irrigation water added in both July and August (NDI). Soil water was monitored in all treatment plots on a monthly basis and immediately before and after each of the four 1.5-inch irrigation events. Herbage standing crops were estimated on a monthly basis by clipping, drying, and weighing herbage from 10 small quadrats per treatment plot.

Results: Results showed that substantial rangeland forage can be grown in this region during July, August, and September with adequate precipitation. The fundamental difference between the forage grown during spring and summer was species composition (Fig. 1). For example, in the two non-irrigated treatments (DNI and NDNI), cool-season species dominated annual production, with cool-season perennial grasses (CSPG) making up 30% of production, cool-season annual grasses (CSAN) making up 20%, and warm-season perennial grasses (WSPG) making up 30%. This is in contrast to estimates in the summer irrigated treatments (DI and NDI), wherein composition consisted of 27% CSPG, 9% CSAG, and 54% WSPG. The dominant CSPG in this study was western wheatgrass, the dominant CSAN was Japanese brome, and the dominant WSPG was blue grama. Note also that forbs were an important component (27%) in the 2 non-drought treatments (NDNI and NDI) where the dominant forb was woolly plantain, a cool-season annual forb.

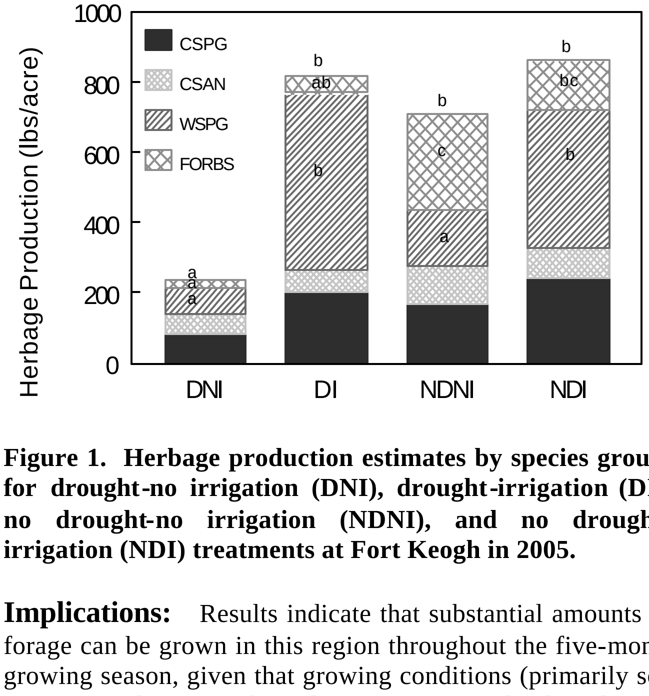

Figure 1. Herbage production estimates by species groups for drought-no irrigation (DNI), drought-irrigation (DI), no drought-no irrigation (NDNI), and no drought-irrigation (NDI) treatments at Fort Keogh in 2005.

Implications: Results indicate that substantial amounts of forage can be grown in this region throughout the five-month growing season, given that growing conditions (primarily soil water) are adequate. This is because our rangeland production base is a mix of cool- and warm-season species which insures a significant portion of the base can respond to opportune precipitation events during either the cool- or warm-season portion of the growing season.

Predicting Grass and Leafy Spurge Response to Management

M.J. RINELLA AND R.L. SHELEY

Problem: Rangeland managers are presented with a complicated and ever-enlarging set of weed management alternatives. Identifying optimal strategies for weed problems requires predicting how strategies will impact weed and forage production. Predicting weed management-induced shifts in production is difficult because these shifts are highly dependent on location-specific factors. Theoretically, population growth models could rescale results from weed experiments so the results better match local conditions. This project tests this theory.

Procedures: We conducted two field experiments at the Author Post Research Farm at Montana State University. In these experiments we combined a range of leafy spurge, Kentucky bluegrass, and western wheatgrass seeding densities. We used data from the field experiments to develop a population growth model.

Results: In comparison to results from field experiments, our model was much more accurate at predicting grass and leafy spurge responses to herbicide use across a range of sites and growing conditions. Figure 1 shows how accurately the model will predict changes in grass production that result from leafy spurge management. The vertical distance between the slanted line and the data points depicts prediction error. The model explained 70% of the variation in grass biomass.

Implications: Our population growth model will be of value to managers as they seek optimal leafy spurge management strategies. We have acquired funding through the Montana Noxious Weed Trust Fund and we will be working with a graduate student to build a grazing component into the model. This will enable the model to predict leafy spurge and forage grass response to sheep and cattle grazing over time. We believe that sheep grazing may actually increase forage availability for cattle, above some threshold density of leafy spurge.

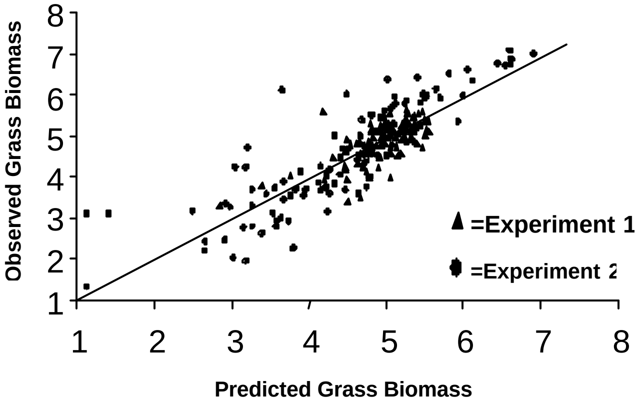

Figure 1. Model predictions of leafy spurge and grass response to weed management actions compared to observed data.

Related Publications

RINELLA, M.J. AND R.L. SHELEY. 2005. Influence of soil water availability on competition among leafy spurge (Euphorbia esula) and grasses. Western North American Naturalist 65:233-241.

A Simple Method for Estimating Leafy Spurge Impact on Forage Production

M.J. RINELLA AND R.L. SHELEY

Problem: Managers must be able to estimate weed impacts to determine if weed control actions are warranted. The impact of weeds on forage production and livestock carrying capacity depends on weed density (e.g., plants/acre). Therefore, managers must measure some index of weed abundance to estimate how much forage they are losing to leafy spurge. The measures of weed abundance that range scientists typically rely on are weed biomass and plant density. Estimating biomass requires clipping and drying the clipped biomass to a constant weight, which is very time-consuming. Measuring density of weeds like leafy spurge is also time-consuming because leafy spurge often produces more than 200 stems/yd^2. Furthermore, knowing stem density is not enough. The height of each stem must also be measured.

Procedures: We collected light probe data from leafy spurge field experiments. Light probe measurements were taken below the leafy spurge canopy, but above associated grasses. Grass biomass was measured shortly after the light probe data were collected and converted to animal unit months (AUM). We used the data to develop an equation that predicts increases in livestock carrying capacity that result from reduction of leafy spurge populations.

Results: The existence of prediction error made it necessary to predict the probability that any given percent increase in AUM would result from leafy spurge control. Figure 1 shows probability distributions and prediction intervals that have a 95% chance of overlapping the actual AUM increase at three sites. The figure also shows the actual percent AUM increase that resulted from leafy spurge removal with herbicides. The 95% intervals overlap the actual increases at all three sites, which illustrates that the model functions properly. The measurements needed to estimate forage increase can be gathered in less than 5 minutes.

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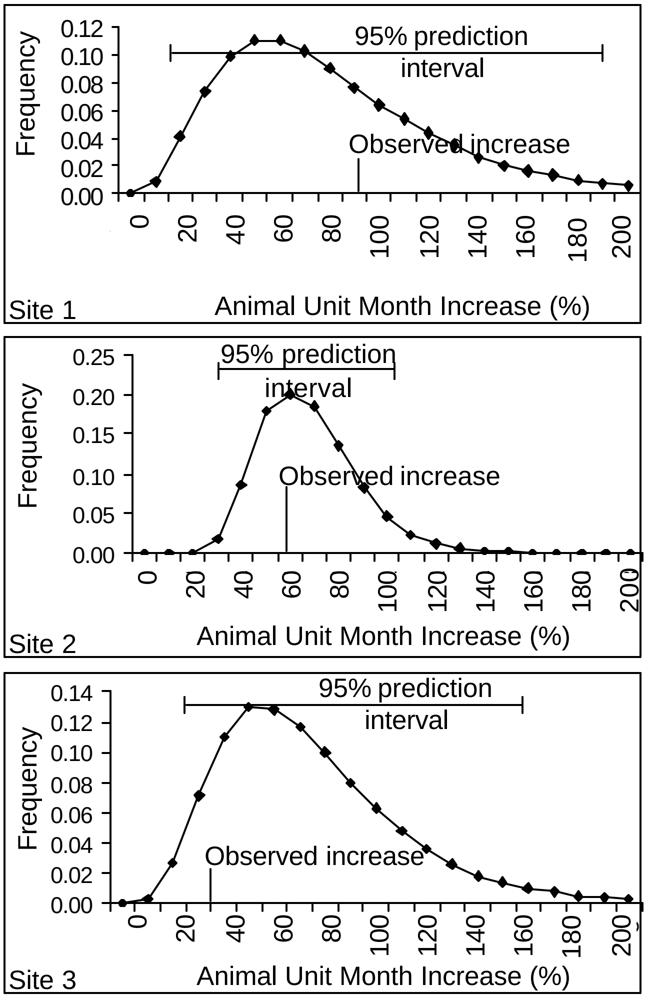

Figure 1. Intervals predicting the increase in animal unit months following leafy spurge control at three rangeland sites. Observed increases were measured in leafy spurge plots treated with herbicide.

Implications: Our light-based method holds promise for estimating leafy spurge impacts on livestock carrying capacity in rangeland. If livestock managers become interested in using this technique, it will be possible to make light probes available through county extension offices. Livestock managers could also purchase their own light probes, which are fairly inexpensive and simple to operate.

Figure 2. Leafy spurge-Kentucky bluegrass-western wheatgrass plots near Bozeman, MT.

Heifer Production on Rangeland and Seeded Forages in the Northern Great Plains

M.R. Haferkamp, M.D. MacNeil, E.E. Grings,
and K.D. Klement

Problem: Pastures seeded to perennial cool-season grasses may be used to reduce grazing pressure on native rangelands and provide quality forage for livestock during selected seasons. Seasonally, weight gains per head and per acre are often, but not always, greater on seeded pastures compared to native rangeland. Observed increases in animal performance often result from increases in both quantity and quality of available forage, and the potential high stocking rates used on seeded pastures. The variable animal responses that have been observed over both years and sites suggest research needs to be conducted within a variety of climate and vegetation types. To better understand responses in a Northern Great Plains environment we compared performance of yearling Line 1 Hereford heifers grazing seeded forages in spring and autumn to those grazing native rangelands at Fort Keogh.

Procedures: Twice-replicated, 7.4-acre seeded pastures of Rosana western wheatgrass, Luna pubescent wheatgrass, Hycrest crested wheatgrass, and a 1300-acre pasture of native rangeland were grazed during spring 2000, 2001, and 2002; native rangeland was grazed during summer each year; and twice-replicated, 8-acre pastures of Alkar tall wheatgrass, Prairieland Altai wildrye, Bozoisky Russian wildrye, NewHy hybrid wheatgrass, and a 250-acre (2000) or 1300-acre (2001 and 2002) pasture of native rangeland were grazed during autumn. Heifers were grazed with other cattle on native rangeland during the spring, summer, and autumn periods.

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Seven heifers per replication grazed the spring pastures for 30 to 45 days from mid to late April through early June. Autumn pastures were grazed for 30 to 55 days, beginning in early September. Length of autumn grazing periods varied among years and forage species because of differences in available forage.

Forage production/availability was assessed by harvesting standing crop to ground level immediately before and after each grazing event on seeded pastures and native rangeland. Selected sites on upland, lowland, and side slopes were sampled on native rangeland. Heifers were weighed at the beginning and end of each grazing period. Forage and diet quality were also determined during the study.

Results: Spring gains on native rangeland were generally lower than on seeded pastures (Tables 1 and 2). Spring gains of heifers were similar to previously reported gains of heifers (1.2 to 1.7 lbs/head/day and 64 lbs/acre) spring grazing Hycrest, Luna, and Rosana here at LARRL.

Summer gains of heifers that grazed seeded pastures in the spring were somewhat less than those continuously grazing native rangeland (Tables 1 and 2). As forage quality declined on native rangeland throughout the summer, heifers that gained more rapidly in the spring may have had a more difficult time obtaining an adequate amount of nutrients to maintain weight gain equal to that of the heifers that grew more slowly in the spring. Late summer grazing has resulted in weight loss in yearling cattle on Northern Great Plains rangelands, but this has not occurred in years with favorable growing conditions.

Improved autumn gains on Prairieland and Bozoisky compared to native rangeland (Tables 1 and 2) may indicate a viable management strategy for pregnant heifers going into winter. Strategies that increase weight and condition of pregnant cattle before winter may reduce winter feed requirements. The relative economic value of these seeded pastures compared to native rangeland and the impact on harvested feed needs were not evaluated in this study.

Spring gains followed a generalized pattern of forage quality among the seeded forages. Hycrest and Luna generally showed greater crude protein and digestibility in diet samples with correspondingly greater weight gain in heifers. Increased gains for heifers grazing Prairieland and Bozoisky in the autumn were also reflective of the increased crude protein and digestibility for these forages.

Annual variation in amount and distribution of precipitation appears to explain some, but not all of the variation in standing crop, forage and diet nutritive quality, and livestock performance. Above-average precipitation in October and November 2000 and June and July 2001, potentially increased standing crops during summer and for some pastures during autumn 2001. The above-average precipitation in June and July 2001 also appeared to increase crude protein concentrations in forage, as well as crude protein and digestibility in diets through the summer of 2001 and at the turn-in date for some of the autumn pastures. Above-average precipitation in May, August, and September 2002 did not appear to stimulate increases in standing crop or forage and diet nutritive quality except in a few cases.

Selecting suitable plant species for seasonal grazing is an important aspect of developing a viable integrated forage system. In an earlier study, we discussed the problems with maintaining stands of pubescent wheatgrass in the 13.2-in precipitation zone in the Northern Great Plains. The 4 forages that were grazed in autumn reportedly have very good to excellent salin-

Table 1. Means for average daily gains of yearling heifers on seeded pastures and native rangeland at Miles City, MT.

Spring	Hycrest crested wheatgrass	Luna pubescent wheatgrass	Rosana western wheatgrass	Native rangeland	
	--------(lbs/head/day)--------				
2000	2.1	2.2	1.7	0.6	
2001	2.2	2.0	1.9	-0.1	
2002	2.2	1.6	1.6	1.6	
Summer on native rangeland					
2000	0.8	0.9	0.7	1.4	
2001	0.9	1.1	0.9	1.7	
2002	1.1	1.2	1.2	1.2	
Autumn	Alkar tall wheatgrass	Prairieland Altai wildrye	Bozoisky Russian wildrye	NewHy hybrid wheatgrass	Native rangeland
2000	-0.2	0.4	0.2	-0.2	-0.8
2001	1.2	2.0	1.8	1.7	1.0
2002	0.6	1.2	0.8	0.5	0.9

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Table 2. Means for average gain per acre of yearling heifers grazing on seeded pastures and native rangeland at Miles City, MT.

Spring	Hycrest crested wheatgrass	Luna pubescent wheatgrass	Rosana western wheatgrass	Native rangeland	
	(lbs/ acre)				
2000	84.90	88.30	68.80	0.70	
2001	57.20	54.10	51.40	-0.10	
2002	75.20	57.10	56.20	2.00	
Summer on native rangeland					
2000	4.20	5.20	3.60	7.90	
2001	5.90	6.80	5.60	11.00	
2002	6.20	7.00	6.80	7.00	
Autumn	Alkar tall wheatgrass	Prairieland Altai wildrye	Bozoisky Russian wildrye	NewHy hybrid wheatgrass	Native rangeland
2000	-7.20	11.50	4.60	-7.60	-9.90
2001	59.10	96.40	79.90	84.30	4.60
2002	30.40	60.90	24.10	25.20	1.60

ity tolerance, are adapted to heavy-textured soils, and are recommended for autumn grazing. However, findings from this study suggest that Bozoisky Russian wildrye is not as well adapted to high pH of Marias clay and silty clay soils as the other cultivars evaluated. Also, use of Alkar tall wheatgrass during autumn does not take advantage of the pattern of forage production and nutritive quality of this grass. Much of the standing crop available to heifers in autumn was the stiff reproductive shoots produced during spring and early summer by this species. The low forage and diet quality for this species emphasize this fact.

Implications: Seeded pastures of cool-season grasses provide livestock managers on western rangelands an opportunity to potentially increase available forage and provide quality forage for grazing livestock. Choosing the best forage for the intended use is critical. Luna, Alkar, and Bozoisky were probably not the best adapted cultivars for the proposed use on the soils at this location.

Findings of this study and others clearly show that seasonal livestock gains may be better on seeded pastures than on native rangeland even with increased stocking pressure. Thus, seeded pastures can be an effective management tool to defer use of native rangeland. Results of this study suggest Hycrest crested wheatgrass would be the best among the cultivars evaluated for grazing in spring and Prairieland Altai wildrye would be the most productive pasture for autumn. Livestock performance results validate recommendations regarding use of complimentary forages based on their agronomic characteristics. However, early spring gains may not be maintained when cattle are moved from seeded pastures to native rangeland for the summer grazing season, and the increased gains may not occur every year. Livestock managers may need to modify their tactics to take full advantage of increased gains on seeded pastures.

Grazing Strategy Effects on Northern Plains Plant Communities

L.T. Vermeire, R.K. Heitschmidt,
and M.R. Haferkamp

Problem: Individual grazing systems are often promoted as a panacea for perceived rangeland management problems, and they are defended with zeal by those who employ them. However, studies of grazing systems over long periods are limited and those directly comparing more than a few grazing strategies at a time are quite limited. Verifying the effectiveness of management strategies is crucial in achieving objectives and improving rangeland resources. The primary objective of this study was to determine the potential long-term impacts of 7 different grazing systems on standing crop and plant community composition of a northern mixed-grass prairie. Secondary objectives were to contrast the impacts of excessively high grazing intensity and moderate stocking, and to assess the effects of timing of grazing and pasture rotation on these grasslands.

Procedures: Seven simulated grazing strategies were applied 6 years to determine effects on plant community composition and standing crop. Grazing treatments were randomly assigned to 14, 15-acre pastures. Treatments were moderate stocking of cattle using 3-pasture rotation (3PR), season-long (SL), high-intensity low-frequency (HILF), short-duration (SDG), 3-pasture winter rotation (3PRw) and spring calving (SpC) systems (Table 1). The final treatment was severe grazing when forage was available (HIGH). Cactus, forb, grass,

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and shrub standing crop were measured 1 year before (1996) and 1 year after grazing treatments (2003). In 2003, the grass component was further divided into western wheatgrass, other cool-season perennial grasses, warm-season perennial grasses, and annual grasses to assess possible changes within the grass component.

Table 1. Schedules of grazing strategies applied to claypan range sites from 1997 to 2002 on Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana.

Grazing System	Year(s)	Grazing Dates
3PR	1997, 2000	1-15 Jun., 15 Jul.-15 Aug.
	1998, 2001	1-15 Jul., 15 Sep.-15 Oct.
	1999, 2002	16-30 Jun., 15 Aug.-15 Sep.
SL	1997-2002	1 Jun.-15 Oct.
HILF	1997, 1999, 2001	4-27 Jun.
SDG	1997-2002	1-3 Jun., 15-17 Jul., 28-30 Aug.
3PRw	1997, 2001	15 Oct.-6 Dec.
	1998-1999	6 Dec.-27 Jan.
	2000	27 Jan.-20 Mar.
SpC	1997-2002	21 Mar.-31 May

Results: Standing crop did not vary among individual grazing strategies for any of the vegetative components measured before grazing treatments. Standing crop was about 45 and 39% less in 2003 than 1996 for grass and total standing crop (Fig. 1). Conversely, cactus standing crop was greater at the study's conclusion. Forb and shrub standing crop in 2003 were similar to levels measured before grazing treatments. Changes in standing crop were primarily weather-related and not believed to be grazing effects. Precipitation was favorable for abundant plant growth in 1996, whereas the primary growth period was generally dry thereafter (Fig. 2).

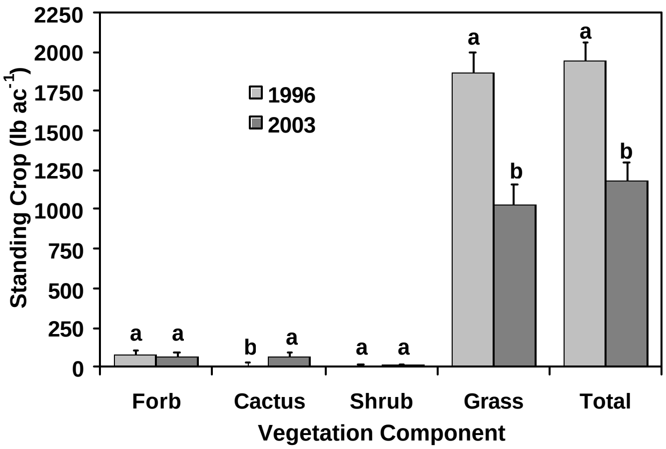

Figure 1. Pre- and post-grazing treatment standing crop and standard errors of forb, cactus, shrub, grass, and total standing crop across grazing strategies at Fort Keogh Livestock and Range Research Laboratory.

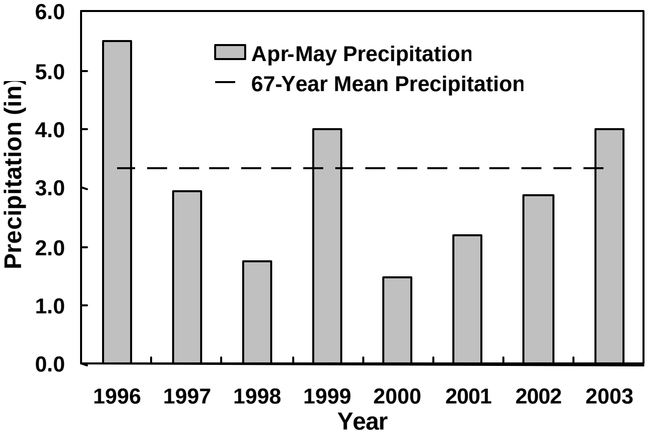

Figure 2. Long-term mean (1937-2004) and study period (1996-2003) April-May precipitation at Fort Keogh Livestock and Range Research Laboratory. Long-term data were from Wiley Field, 7.3 mi. NNW of the study site (Western Regional Climatic Center 2004) and study period data were collected on site.

Stocking rate was not a significant factor affecting major standing crop components. However, HIGH trended weakly toward a steeper rate of reduction in total standing crop between years and reduced annual grass standing crop. Moderate stocking generally left more standing crop than HIGH during the grazing period. The lack of stocking rate effect between pre- and post-treatment years indicates the claypan sites were resilient to stocking rate effects that may have occurred during treatment. Drought conditions for 5 of the 6 treatment years reduced standing crop and may have moderated the stocking rate effect by making utilization relatively high for both stocking rates.

Rotational systems did not produce measurable changes in standing crop or functional group composition. An intended benefit of rotational grazing is to allow plant growth and recovery between defoliation events. Opportunities for plants to respond to rest periods were limited by dry conditions during much of the study. However, the majority of plant growth is normally restricted by climate to mid- and late spring in the Northern Great Plains and drought is common. Considerable spring rest periods were afforded SDG and HILF pastures and 3PRw pastures were not used during the growing season. Given the lack of standing crop or species composition response induced by these strategies, any advantages offered plants by pasture rotation appear to be short-term at best on claypan sites.

Forb and shrub standing crop were each similar between pre-June and post-May grazing treatments (Fig. 3). Pre-June pastures had 17% greater grass standing crop and 23% greater total standing crop than pastures grazed after May. Although these results appear contrary to regional management recommendations to limit grazing before June, differences in grass and total standing crops were accounted for, almost to the pound, by increased annual grass and cactus. Annual grass standing crop was 323 lbs/acre on pre-June pastures and 119

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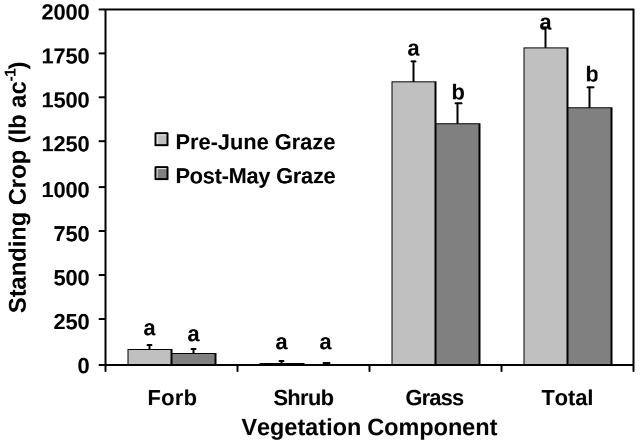

Figure 3. Standing crop and standard errors of forb, shrub, grass and total standing crop on pre-June and post-May grazed pastures at Fort Keogh Livestock and Range Research Laboratory.

lbs/acre on post-May pastures. Cactus standing crop did not differ by timing of grazing in 1996, or between years for late-grazed pastures. On early-grazed pastures, cactus increased to 167 lbs/acre compared to the 14-lb/acre mean of 2003 late-grazed and pre-treatment measurements. Prickly pear seed germinates late spring through early summer and completes most pad growth by early June. Reduced standing crop during late spring may favor prickly pear establishment and growth, leading to the observed increase on early-grazed pastures.

Implicaations: Changes in standing crop over time and limited change among grazing practices indicate northern mixed prairie is most responsive to weather and resistant to changes in plant community composition. Grazing practices appear capable of inducing only minor changes in annual grass and cactus on claypan sites during generally dry periods.

Effects of Livestock Removal from Northern Plains Rangelands

L.T. VERMEIRE, R.K. HEITSCHMIDT,
AND M.R. HAFERKAMP

Problem: Livestock exclusion has been proposed to restore rangeland health. However, large grazers were abundant in the Northern Great Plains prior to livestock introduction and herbivory can be a key factor in maintaining the structure and function of many rangelands. The complete removal of large grazers may be expected to alter plant communities that were historically grazed, but there is little evidence to indicate how long-term livestock exclusion will affect these communities and no guarantee the changes would improve rangeland productivity or the integrity of those sites. We evaluated current-year biomass, species composition, and species richness on livestock-grazed and livestock-excluded sites over a 10-year period to determine some potential effects of livestock exclusion in the semi-arid Northern Great Plains.

Procedures: Four 30-acre livestock exclosures were established and paired with adjacent, moderately-grazed sites in 1993. Current-year live and dead biomass were sampled annually at peak standing crop. Biomass was determined by clipping vegetation in 20 quadrats measuring 0.3 yd^2 in permanent key areas of each exclosure and grazed site. Plants, including cacti and shrubs, were sorted in the field by species from 1994 through 2003. Shrub biomass was collected by stripping leaves from shrub limbs within quadrats. Species richness was calculated as the average number of species per quadrat to assess effects of livestock grazing and livestock removal on plant diversity.

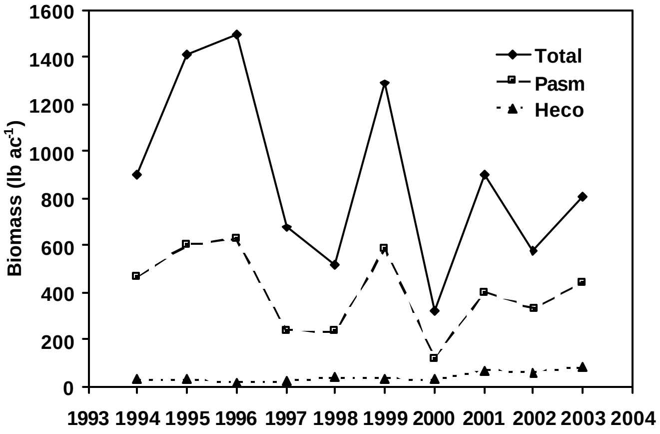

Figure 1. Total, western wheatgrass (Pasm), and needle-and-thread (Heco) biomass across years and grazing treatments on Fort Keogh Livestock and Range Research Laboratory, 1994-2003.

Results: Threadleaf sedge, Junegrass, non-brome annual grasses, other perennial cool-season grasses, forbs, woody plants, and cacti comprised about 22% of the biomass and each was similar across years and grazing treatments. Western wheatgrass, Sandberg bluegrass, needle-and-thread, warm-season shortgrasses, other perennial warm-season grasses, and total biomass varied annually, but biomass of each was similar between grazing treatments (Fig. 1). These species accounted for about 59% of the biomass. Annual brome biomass and composition, and warm-season shortgrass composition each varied between grazing treatments, depending on the year. Annual brome biomass was greater within exclosures 2 years and composition was greater within exclosures 3 years. Annual bromes were greater on grazed sites only during 1996 (Fig. 2 and 3). The cause of increased annual brome on grazed sites is not readily explainable and brome frequency was similar between grazing treatments in 1996. Annual brome biomass, composition, or frequency was greater within

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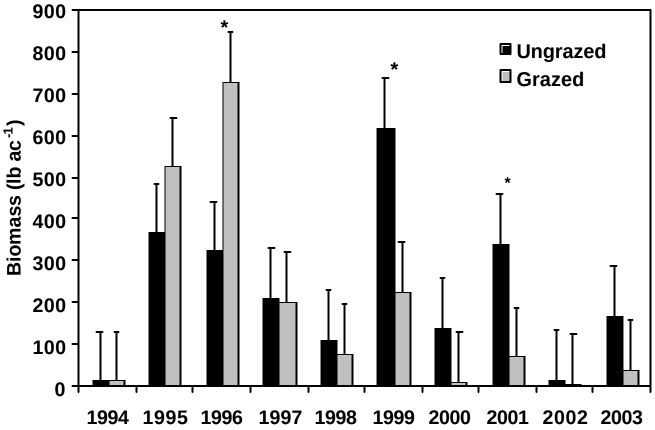

Figure 2. Annual brome biomass on cattle-grazed and livestock excluded sites on Fort Keogh Livestock and Range Research Laboratory, 1994-2003. Bars denote standard errors and stars indicate statistical differences between grazing treatments for that year.

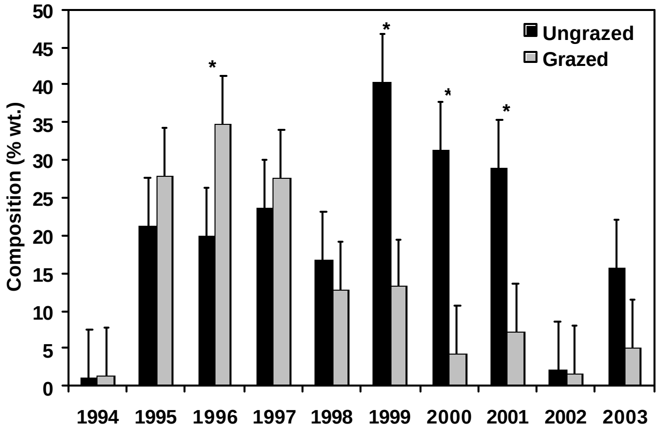

Figure 3. Annual brome composition of total biomass on cattle-grazed and livestock excluded sites on Fort Keogh Livestock and Range Research Laboratory, 1994-2003. Bars denote standard errors and stars indicate statistical differences between grazing treatments for that year.

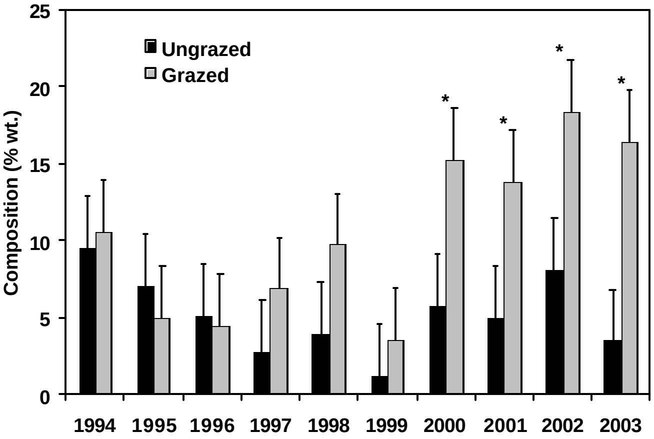

Figure 4. Warm-season shortgrass composition of total biomass on cattle-grazed and livestock excluded sites on Fort Keogh Livestock and Range Research Laboratory, 1994-2003. Bars denote standard errors and stars indicate statistical differences between grazing treatments for that year.

exclosures from 1999 to 2003. Biomass of warm-season shortgrasses did not increase from 2000 to 2003, but comprised a greater portion of the total biomass on grazed sites (Fig. 4). Early signs of this trend coincide with the onset of drought and were likely magnified by selective grazing of cool-season species. Species richness varied by year (5 to 8 species per quadrat), but was similar between grazing treatments. Introduced species were more abundant within exclosures (208 lbs/acre) than on grazed sites (63 lbs/acre).

Implications: Exclosures and grazed sites were largely similar. Although rest from grazing may be beneficial in some aspects, there was no indication that 10 years of livestock exclusion increased plant biomass or diversity. The presence of annual bromes and introduced species as a whole increased on non-grazed sites. Because of the potential for introduced species to alter rangeland structure and function, the greater abundance of introduced species in livestock excluded sites may over-ride possible benefits of rest from grazing.

Fire and Grazing Effects on Vegetation and Biological Soil Crusts

J.M. MUSCHA, L.T. VERMEIRE, AND M.R. HAFERKAMP

Problem: Biological soil crusts are composed of mosses, cyanobacteria, green algae, lichens, microfungi and bacteria. Rangelands may benefit from biological soil crusts because crusts have been shown to significantly reduce wind and water erosion and contribute to soil organic carbon and nitrogen. Some have reported biological soil crusts are susceptible to disturbances, such as livestock grazing and fire. However, little information exists about fire and grazing effects on biological soil crusts in the Northern Great Plains.

Procedures: The study was located on a silty range site at Fort Keogh. Dominant grass species at this site are western wheatgrass, needle-and-thread, blue grama, threadleaf sedge, Japanese brome and Junegrass.

Four permanent quadrats (8 X 20 inches) were selected based on presence of lichens and mosses to measure percent ground covered in each of 4 replications of 3 treatments. Treatments were autumn fire in 2003 (Burn), moderate grazing with 50% removal in May and June of 2004 (Graze), and no fire or grazing (control). Percent of ground covered by grass, moss, lichens, forb, litter, and bare ground were measured before treatments were applied in 2003 and after treatments were applied in 2004.

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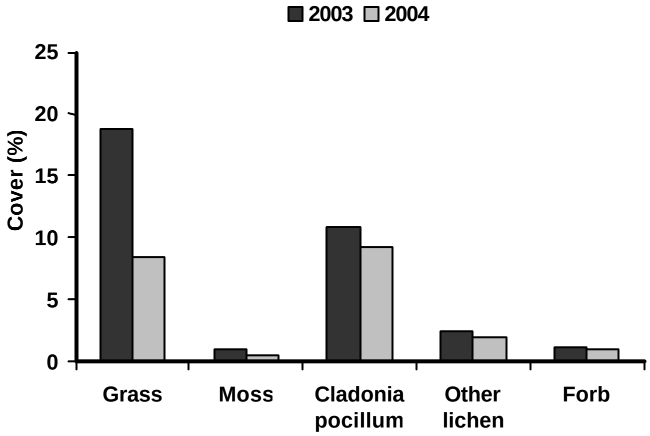

Figure 1. Percent ground cover by grass, moss, *Cladonia pocillum*, other lichens and forb across treatments in 2003 and 2004.

Results: Percent of ground covered by grass, moss, *Cladonia pocillum* (dominant lichen) and other lichens decreased across treatments in 2004 (Fig. 1). Percent forb cover was not affected after treatments were applied. Litter cover was similar across all plots in 2003 before treatments were applied. Litter increased in the second year for all treatments, but at a slower rate in the burned plots (Fig. 2). The spring drought of 2004 contributed to the decrease in grass cover for all treatments and probably decreased the decomposition rate of litter. Before treatments were applied, percent bare ground was less in the burned plots compared to the control and grazed plots. After treatment, percent bare ground only increased in the burned plots. Control and grazed plots decreased in bare ground cover after treatment (Fig. 3). Seven lichen and two moss species were encountered at this site. Despite nearly complete combustion of herbaceous material, the structural matrix of crusts was left intact following a late-autumn fire. Burning and grazing each reduced moss cover (Fig. 4). Previous studies have shown mosses to be more susceptible to grazing and fire than lichens. A delayed fire effect may be expected for biological soil crusts, given the increase in bare ground and alteration of microclimate.

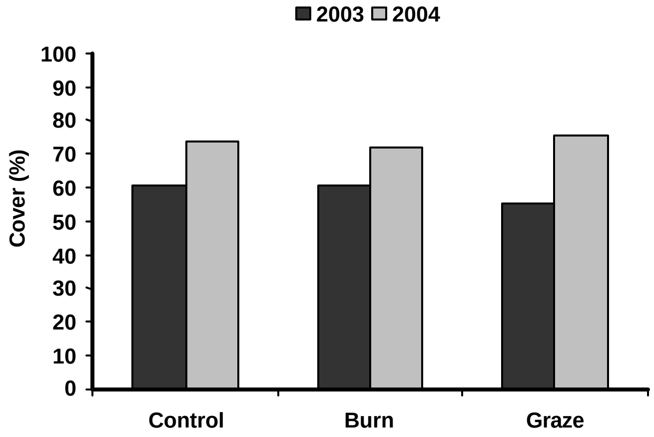

Figure 2. Percent litter ground cover on control, burned and grazed sites in 2003 and 2004.

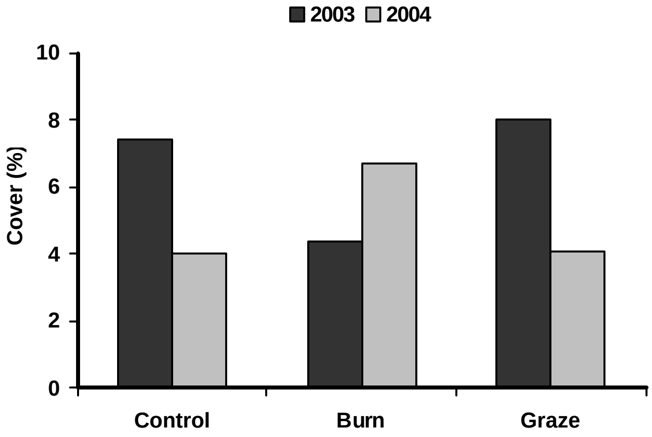

Figure 3. Percent bare ground on control, burned and grazed sites in 2003 and 2004.

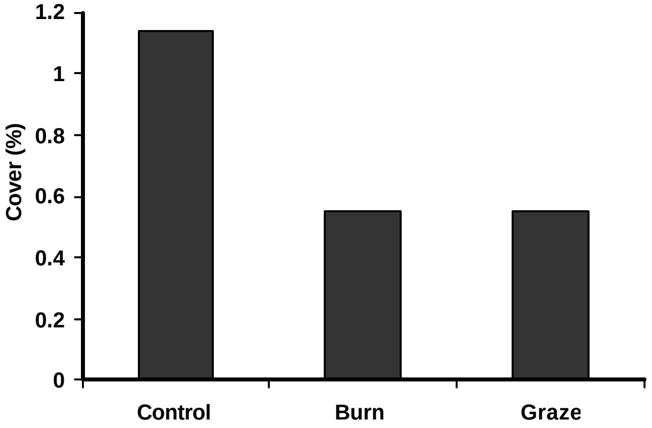

Figure 4. Percent moss ground cover on control, burned and grazed sites.

Implications: Biological soil crusts increase soil water retention which enhances vascular plant establishment. They have also been shown to aid in discouraging annual weeds. Recent research suggests crusts can be used as indicators of improved rangeland health. Additional monitoring of biological soil crusts can assist with determining the effects of grazing and prescribed fire management practices on rangelands.

First-Year Effects of Summer Fire and Post-Fire Grazing

J.L. ROSE, L.T. VERMEIRE, AND D.B. WESTER

Problem: Summer wildfires occur naturally throughout the Northern Great Plains. Land managers often make grazing deferment decisions based on research conducted in other vegetation types or fires that occurred in different seasons. It is important for land managers to have access to research that applies to the area in order to make sound decisions. The objectives of this study were to document fire and post-fire grazing effects on species richness (number of species in a defined area), density, and frequency; and to whether these community properties are changed in the first growing season following fire.

Procedures: Five fire and grazing treatments were applied to twenty, 1.85-acre plots. Treatments included: no fire and 0% utilization, fire and 0% utilization, fire and 17% utilization, fire and 34% utilization, and fire with 50% utilization. Fire was applied in August of 2003. Grazed plots were stocked with ewes from late June through mid-July 2004. Four cages (3 X 6.5 ft) were placed in each grazed plot to exclude sheep grazing. Forage utilization was determined by comparing the amount of forage within cages to that adjacent to cages and open to sheep grazing. Species richness and frequency were measured within 20 quadrats (0.3 yd^2) along permanent transects (82 ft). Frequency and density of shrub and cactus species were measured in 20 randomly placed quadrats (0.3 yd^2) in each plot. Sampling was done in mid-July before (2003) and after (2004) treatment.

Results: Summer fire and post-fire grazing did not change species richness. Fire alone did not affect prickly pear cactus or pincushion cactus density, although the number of live pads was reduced (Fig. 1). Fringed sage density and frequency were sharply reduced by fire (Figs. 1 & 2). Fire-induced mortality of fringed sage appeared greatest for seedlings. Forb frequency increased following summer fire.

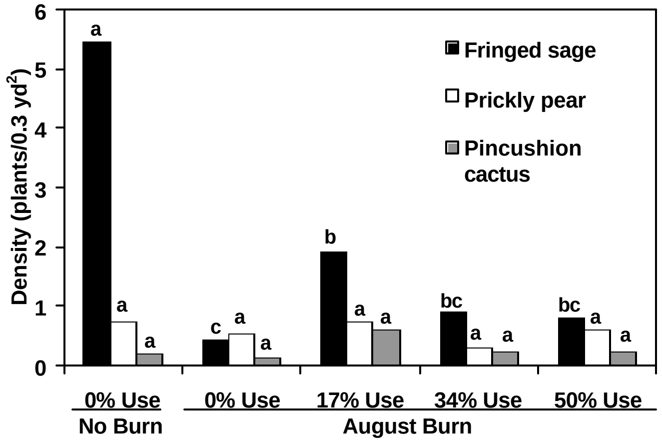

Figure 1. Density of fringed sage, prickly pear, and pincushion cactus following summer fire and post-fire grazing treatments. Treatment means with the same letter within a species are not different.

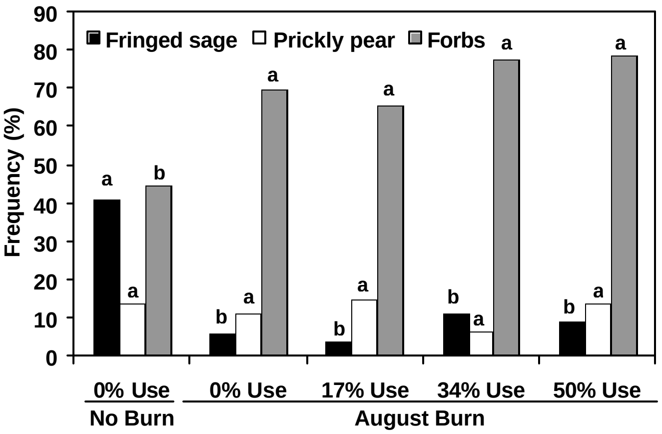

Figure 2. Frequency of fringed sage, prickly pear, and forbs following summer fire and post-fire grazing treatments. Treatment means with the same letter within a species are not different.

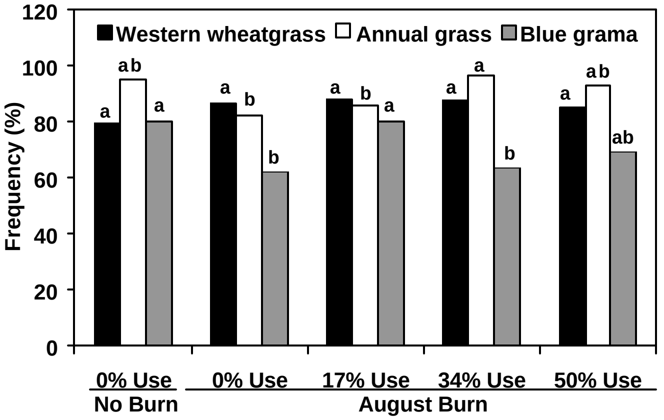

Figure 3. Frequency of western wheatgrass, blue grama, and annual grasses following summer fire and post-fire grazing treatments. Treatment means with the same letter within a species are not different.

Annual grass frequency was not affected by burning, but was affected by forage utilization among burned plots (Fig. 3). Annual grass was encountered in 82% of the samples with no grazing and present 92% of the time with 34 and 50% forage utilization. Western wheatgrass and needle-and-thread, the dominant cool-season grasses, showed no change in frequency with fire or grazing. However, other cool-season perennial grass (prairie junegrass, green needlegrass, Sandberg bluegrass, and crested wheatgrass) frequency increased from 66% before fire to 74% following fire. Frequency of blue grama differed among treatments, but trends were not apparent as a response to fire or the gradient in forage utilization. Associated data not presented here reveal that blue grama biomass decreased with increasing forage utilization, as may be expected. Other warm-season grasses (sand dropseed and buffalograss) and threadleaf sedge were not affected by grazing or fire treatments.

Implications: Fire may affect fringed sage, cactus, and some grass species. However, summer fire does not appear to have a detrimental effect on dominant grass species. Changes in forage utilization affected only annual grass frequency. Early results indicate grazing during the first growing season after summer fire is not detrimental to dominant perennial species.

Grasshopper Egg Mortality Explained by Laying Strategy and Fire Intensity

D.H. BRANSON AND L.T. VERMEIRE

Problem: Few studies have examined if rangeland fire can be used to help manage pest grasshopper species. Grassland fires appear capable of having positive or negative effects on grasshopper populations, with the timing and intensity of a fire playing important roles. Grasshopper species laying shallow egg pods appear to be negatively affected by late-summer or fall rangeland fires, but the mechanisms responsible for this pattern are unknown. For example, populations of the whitewhiskered grasshopper declined following fall fires in both Oklahoma and western North Dakota. Most grasshopper species in the northern Great Plains lay egg pods in late summer and overwinter as eggs before hatching the following spring. Since the size of egg pods and the depth and orientation they are laid in the soil varies between grasshopper species, soil temperatures in the vicinity of egg pods during a fire should differ between species and with the intensity of a fire. In addition, soil temperatures and the duration of heat during rangeland fire increase with the amount of standing biomass. Therefore, the amount of plant biomass could be a determining factor in whether a given fire kills grasshopper eggs in the soil. We examined the effects of simulated grassland fire intensities on egg survival and hatching using a pest grasshopper species laying shallow egg pods (whitewhiskered grasshopper) and a pest species laying deeper, vertically-oriented egg pods (migratory grasshopper) in a laboratory experiment. The whitewhiskered grasshopper lays small egg pods of 3 to 5 eggs close to the surface, typically in the top ¼ inch of soil. In contrast, the migratory grasshopper, which is often the most abundant grasshopper in eastern Montana, lays egg pods in a vertical orientation, with the midpoint of the egg pod typically ¾ of an inch below the soil surface. The purpose of this experiment was to examine if exposure to heat during rangeland fires was the mechanism responsible for observed reductions in populations of the whitewhiskered grasshopper following fire. The direct effects of soil temperature regimes occurring during rangeland fires on the mortality of grasshopper eggs have not been previously examined. The experiment will help determine conditions for which fire can be used as a management tool to reduce pest grasshopper species.

Procedures: Four-inch diameter, intact soil cores were collected from the field and placed in plastic containers. Adult whitewhiskered and migratory grasshoppers were caught at a native mixed-grass prairie site in August 2004. Individuals of each species were placed in screen cages containing approximately 20 soil core containers for egg pod laying. After egg pod laying was complete, fire was simulated using a propane heater placed above the soil surface. Fire treatment levels were chosen to be representative of surface temperatures during rangeland fires over a range of fuel loads typically found in grasslands. Three temperature treatments and a control treatment with no fire were used for each species, with 10 replicate soil cups in each treatment (Fig. 1). Times used for treatments were 0 seconds (control), 9 seconds (1850 lbs/acre of standing biomass), 23 seconds (2700 lbs/acre of standing biomass), and 46 seconds (4200 lbs/acre of standing biomass). Following the simulated fire, soil core containers were watered and placed in a refrigerator for 3 months to cold diapause the eggs. The containers were then placed in a warm environmental chamber and hatchling grasshoppers were counted daily until all hatching ended. After hatching was complete, all remaining unhatched eggs were removed from the soil and counted. The proportion of eggs hatched in each cup (number hatched/total number of eggs) was used for the statistical analysis of treatment effects.

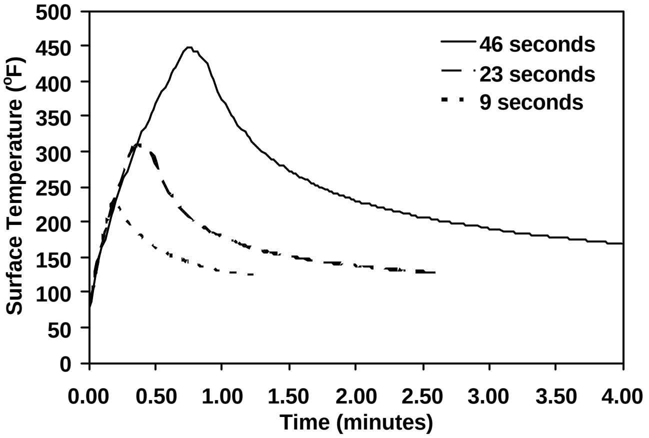

Figure 1. Soil surface temperature over time when exposed to heat treatments of 46, 23, and 9 seconds.

Results: Fire intensity did not have large effects on egg mortality in the migratory grasshopper (Fig. 2). The midpoint of egg pods of the migratory grasshopper is approximately ¾ of an inch below the soil surface. The soil temperature at this depth increased above the ambient temperature only in the 46-second fire treatment, indicating that the migratory grasshopper egg pods are well protected from the effects of rangeland fires even when standing biomass is abundant.

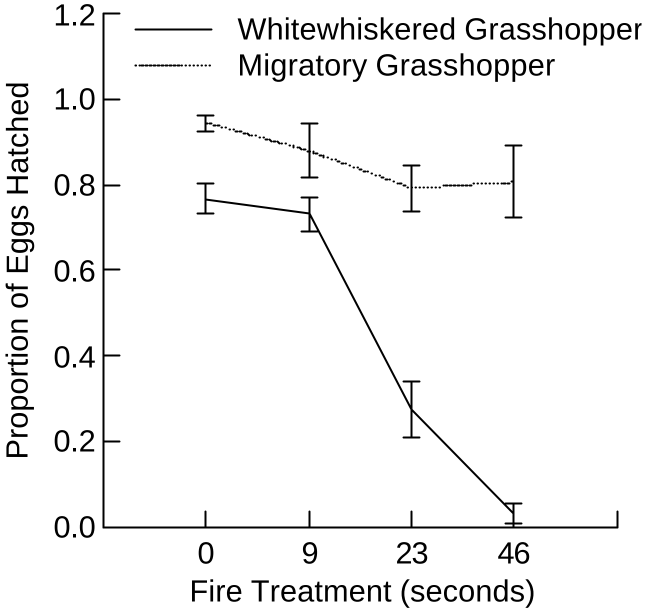

Figure 2. Proportion of eggs hatched by treatment for each grasshopper species.

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In contrast, the proportion of whitewhiskered grasshopper eggs that hatched was strongly reduced at the two highest fire intensity levels (23 and 46 seconds) (Fig. 2). At the moderate biomass fire intensity (23 seconds), the proportion of eggs hatched was reduced by two-thirds. In the highest fire intensity treatment, no eggs hatched in 12 of the 14 containers, indicating that high biomass fires would nearly eliminate the whitewhiskered grasshopper in the year following a fall fire. An average of 35% of unhatched whitewhiskered grasshopper eggs in the highest fire intensity treatment were visibly charred, a further indication that the simulated fire was the direct cause of egg mortality. The horizontal orientation and shallow location of whitewhiskered grasshopper egg pods likely results in high temperatures for all eggs in a given egg pod during intense fires. The proportion of eggs hatching was not affected by the lowest fire intensity treatment (9 seconds), when soil temperatures ¼ of an inch below the surface remained lower than 100°F. Grasshopper species that lay egg pods at somewhat deeper than the whitewhiskered grasshopper could be controlled by fires if they preferentially lay egg pods in clumps of plants. Grasshopper species that lay eggs primarily in areas of bare ground would be less likely to be affected by fire even when egg pods are near the soil surface. Furthermore, wildfires are heterogeneous and do not burn all areas evenly. However, the results indicate that fires occurring in areas with at least 2450 lbs/acre of standing biomass would selectively control populations of the whitewhiskered grasshopper.

Implications: This study is the first that has linked field observations of grasshopper populations following a fire to the mechanisms responsible for the observations. This study suggests that fire may be useful as a management tool for some, but not all pest grasshopper species. By examining other pest grasshopper species that lay shallow egg pods, we can determine how often burning could be used to help control grasshopper populations in the northern Great Plains. In addition, we are conducting field experiments to examine other direct and indirect effects of rangeland fire on grasshopper populations.

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Figure 3. Scorched grasshopper and smoldering sagebrush during an August prescribed fire at Fort Keogh.

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Fort Keogh Personnel

USDA-Agricultural Research Service

Lee Alexander	Molecular Geneticist
Jack Attig	Administrative Officer
Diona Austill	Research Leader Secretary (OA)
Susan Bellows	Physiology Technician
Janice Berger	Administrative Clerk (OA)
Tom Geary	Reproductive Physiologist
Michelle Griffin	Genetics Technician
Elaine Grings	Animal Nutritionist
Marshall Haferkamp	Rangeland Scientist
Rod Heitschmidt	Supervisory Rangeland Scientist
Whisper Kelly	Nutrition Technician
Eugene Life	Safety Officer
Nina Lynch	Rangeland Technician
Mike MacNeil	Geneticist
Sue Miles	Office Automation Assistant
Cheryl Murphy	Rangeland Technician
Jennifer Muscha	Rangeland Support Scientist
Kathy Neary	Genetics Technician
Mary Susan Reil	Nutrition Technician
Vicki Reisenauer-Leesburg	Statistician
Matt Rinella	Rangeland Scientist
Andrew Roberts	Physiologist
Aaron David Roth	Rangeland Technician
Brooke Shipp	Physiology Technician
Sharon Stanton	Information Technology Specialist
Rod Stieg	Air Conditioning Equipment Mechanic
Lance Vermeire	Ecologist
Richard Waterman	Animal Nutritionist (Weeds)

Montana State University Extension

Larry Brence	Area Director
Vacant	Beef Specialist

Montana Agricultural Experiment Station

Doug Armstrong	Research Assistant I - Nutrition
Butch Arnoldt	Research Assistant I - Feedlot
Eddie Arnoldt	Equipment Mechanic
Benny Bryan	Research Technician I - Farm/Feedlot
Lance Gierke	Research Assistant I - Physiology
Rick Harris	Research Technician I - Physiology
Lee Hendry	Maintenance Worker
Jim Howard	Research Assistant I - Farm/Feedlot
RJ Hubbard	Research Assistant I - Genetics
Justin Kiel	Research Assistant I - Farm/Feedlot
Mike Landers	Research Assistant I - Genetics
Sandra Lockie	Administrative Associate II
Tom Mott	Research Assistant II - Genetics
Jerry Nunn	Research Assistant I - Physiology
Dave Phelps	Research Associate - Physiology
Lynn Scheid	Research Assistant I - Farm/Feedlot
Phil Smith	Heavy Equipment Operator
Ken Strobel	Maintenance Supervisor
Cody Taylor	Research Assistant I - Genetics
Mike Woods	Research Assistant I - Physiology

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