RESEARCH UPDATE 1999

Rod Heitschmidt
Research Leader

Fort Keogh
Livestock and Range Research Laboratory
USDA-Agricultural Research Service
in cooperation with
Montana Agricultural Experiment Station
Rt. 1 Box 2021
Miles City, MT 59301
Phone: 406-232-4970
Fax: 406-232-8209
Homepage: http://www.larrl.ars.usda.gov

Forward

The Fort Keogh Livestock and Range Research Laboratory is a 55,000 acre USDA Agricultural Research Service facility run in cooperation with the Montana Agricultural Experiment Station. The Laboratory was established in 1924 following the closure of the Fort Keogh Army Remount Station which was a remnant of the original Fort Keogh Army fort established in 1877.

The broad mission of the Laboratory is to develop ecologically and economically sustainable range livestock production system that ultimately meet consumer needs. Research is multi-disciplinary revolving around four broad disciplines: 1) rangeland management and ecology; 2) beef cattle genetics; 3) range animal nutrition; and 4) beef cattle reproductive physiology. The objective of this publication is to provide other researchers, agency personnel, rangeland agriculturalists (i.e., ranchers and farmers), and other interested customers with an overview of recent research activities and findings at Fort Keogh.

We believe it imperative that readers understand that agriculture research, such as that outlined herein, is the foundation upon which the American dream is built because until agriculture works, nothing else matters. Agriculture is America's primary and largest industry and its continued success is dependent first and foremost on successful research and development programs such as those outlined herein. The economic well being of the entire United States is linked closely to: 1) the conservation of its natural resource base, particularly soil and water; and 2) continued advancement in the development of new agriculture technology. In the Northern Great Plains, this linkage is most closely tied to the continued conservation of rangeland resources and the development of rangeland livestock production technology. As such, the continued success of the Fort Keogh research program is critical to the long-term economic well being of Northern Great Plains agriculture specifically and the Northern Great Plains region in general.

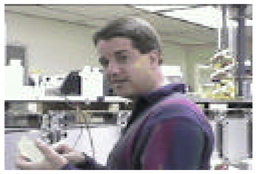
USDA-ARS Fort Keogh LARRL
Administrative, Office and Lab Building

US Department of Agriculture in cooperation with Montana Agricultural Experiment Stations, Fort Keogh Livestock and Range Research Laboratory, Rt. 1 Box 2021, Miles City, MT 59301. (406) 232-4970.
Front Page Picture from ARS Magazine, Nov. 1991.

Updated June 1999.

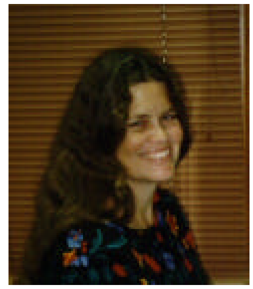
The Authors

Dr. Robert A. Bellows
Research Physiologist
bob@larrl.ars.usda.gov

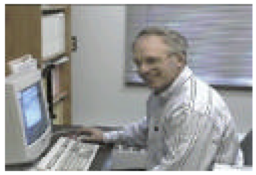


Dr. Michael D. Grosz
Molecular Geneticist
grosz@larrl.ars.usda.gov

Dr. Thomas W. Geary
Research Physiologist
tgeary@larrl.ars.usda.gov



Dr. Elaine E. Grings
Research Animal Scientist
elaine@larrl.ars.usda.gov



Dr. Michael D. MacNeil
Quantitative Geneticist
mike@larrl.ars.usda.gov

Dr. Rick Funston
Beef Extenstion Specialist
rick@larrl.ars.usda.gov

Dr. Marshall Haferkamp
Rangeland Scientist
marshall@larrl.ars.usda.gov

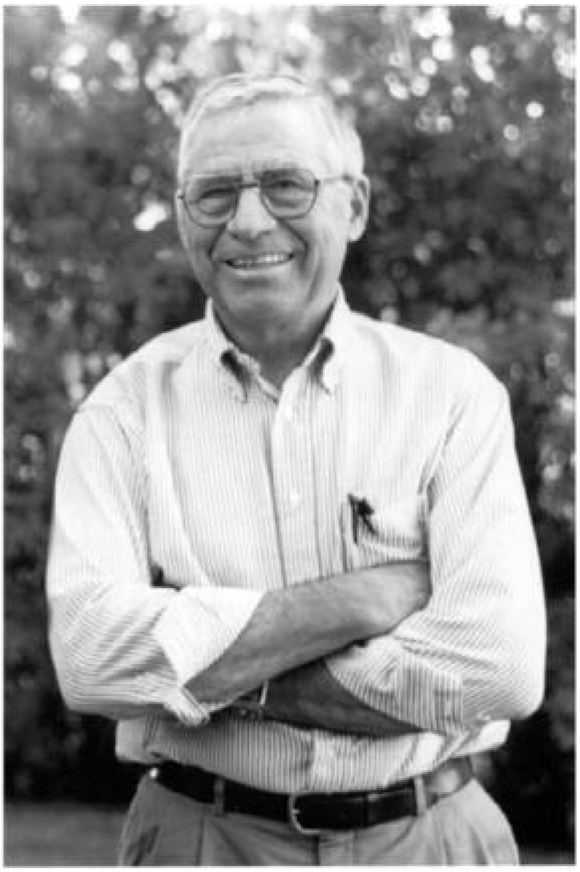
Dr. Robert E. Short
Research Physiologist
bshort@larrl.ars.usda.gov

Dr. Rod K. Heitschmidt
Research Leader and
Rangeland Ecologist
rod@larrl.ars.usda.gov

Dr. Eric Antoniou
Molecular Geneticist
eric@larrl.ars.usda.go

Cooperating Authors

D.C. Adams, University of Nebraska-Lincoln, Inst. of Agric. & Nat. Res., North Platte
S.E. Bellows, Bio. Lab. Tech. - Phys.- Fort Keogh
N.R. Bellows, Res. Ass. Nutrition, MAES, Ft. Keogh
G.L. Bennett, Production Systems Research, USDA-ARS, Clay Center, Nebraska
K.K. Bertrand, University of Georgia, Athens
R.W. Caldwell, Grad. Student, University of Missouri, Columbia
J. Crouch, American Angus Ass., St. Joseph, MO
P.O. Currie, Retired Range Scientist, Fort Keogh
G.B. Ferreira, Dept. de Zootecina, Universidade Federal de Santa Maria, Brazil
S. Ford, Iowa State University, Des Moines, Iowa
N. Gengler, Charge de Recherches, Fonds National Belge de la Recherche Scientifique, Belgium
P.C. Genho, Deseret Cattle and Citrus Ranches, St. Cloud, Florida
J.B. Hall, Beef Cattle Extension Specialist, Virginia Polytechnic Institute
W.O. Herring, Dept. Animal & Dairy Sci., University of Georgia, Athens
A.L. Hild, Ass. Prof. Rangeland Science, University of Wyoming, Laramie
B.S. Hould. Asst. to the Supt., MAES, Fort Keogh
M.G. Karl, Rangeland Scientists, US Forest Service, Boise, Idaho
K.D. Klement, Rangeland Tech., Fort Keogh
L.A. Kriese, Dept. Animal & Dairy Sci., Auburn University, Auburn, Alabama
S. Kronberg, University of South Dakota, Brookings
M.A. Lammoglia, Gen Ova, San Antonio, TX
S.N. McNeley, University of Wyoming, Laramie
S.A. Moore, Deseret Cattle and Citrus Ranches, St. Cloud, Florida
S. Newman, Tropical Beef Centre, CSIRO Div. of Tropical Anim. Prod., Australia
F. Pariacote, UNEFM, Dept. de Produccion, Venezuela
D.A. Phelps, Research Associate, Fort Keogh
J. Rosazza, Pharmaceutical Chemist,University of Iowa, Iowa City
D.D. Simms, Consolidated Nutrition, Omaha, NE
W.M. Snelling, BeefBooster Management Ltd., Canada
R.B. Staigmiller, Retired Physiologist, Absorkee, Montana
J.J. Urick, Retired Geneticist, Fort Keogh
L.W. VanTassell, Ass. Professor Agricultural Economics, University of Wyoming, Laramie
L.D. VanVleck, Geneticist, USDA-ARS, Clay Center, Nebraska
J.D. Volesky, Range Scientist, University of Nebraska-Lincoln, North Platte
C.B. Williams, Production Scientist, USDA-ARS Clay Center, Nebraska



Bill Almy, Producer of the Year
Fort Keogh Open House June 1999

Producer Recognition Award

You can generally find Bill Almy with his ear pressed to the phone. If not, you can guess that he'll be doing something in the lines of fixing, scheming, buying, selling, riding, driving... If you find him napping, mark your calendar.

Born on September 7, 1926 in Philadelphia, Pennsylvania, this first of seven children of William Ellery and Gertrude Thayer Almy was christened William Ellery Almy, Jr. "Billy" was raised near Valley Forge, approximately 30 miles west of Philadelphia. His first brush with agriculture occurred at age 12, when he climbed the fence at his Grandma Thayer's and fell into the chicken yard with the chickens. As a child, he was active in 4-H, raising pigs. Although it was leased out, Billy's chores included other farming responsibilities at the Diamond Rock farm. A family rumor has it that the farm was purchased to keep Billy involved in wholesome activity, since it was evident that he would create activity if not provided with it.

After graduating high school at age 16, Bill attended the University of Pennsylvania with studies in engineering. He also served in the Army Air Corp. It was during this time that he took private flying lessons and soloed with the funds garnered from card games with fellow corpsmen. Inspired by childhood readings of the Jack London novels, Bill struck out for Alaska. The deliberately vague history of this era was always explained to the children that he "got lost on the way to Alaska and wound up in Alzada." It was in 1948 at this very southeastern part of Montana that he began his career in agriculture, which continues to this day.

His first Montana ranch hand job was at the Jim Oliver ranch. Later he met and courted country schoolteacher Joyce Darlene Oscliner. After their marriage November 23, 1951, he brought his bride to his quarters on the Little Missouri, where he held a lease on the Walt Ford place. They later leased the Davenport place from Jim Newland. During these years, three trips were made to Belle Fourche, S.D. to "receive shipment" of three kids, William Ellery III, Curtis Thayer, and Dawn Darlene.

In 1960, Bill and Joyce, in partnership with former Pennsylvanian Loren Ratcliff, purchased the Hamilton Brothers ranch at Ismay, Montana. In keeping with the personal history of a Pennsylvania (Keystone State) upbringing, Bill had earlier created the single iron Keystone brand. The new corporation was also named Keystone Ranches. Bill and Joyce bought out the partnership after about one year. They later added Elizabeth Ann to complete their family of four children.

Bill utilized his engineering skills in executing various improvements to the 22,000-acre ranch. This included providing vital water to ten sections with two buried railroad tank car cisterns, situated on elevation serving fourteen miles of pipeline. Twenty reservoirs or spring developments supplement the seasonal flows of the Pennel and O'Fallon Creeks. Eighteen miles of cross fencing were added, as were the necessary calving facilities and steel corrals.

Early years found sheep and cattle grazing on Keystone Ranches, until the coyotes won. After that, the main concentration was on building a genetically improved cow/calf herd. Efforts included incorporating the Line 1 Bulls and "Composite Bulls" from the Fort Keogh Research Station at Miles City. In 1968, artificial insemination was employed at the ranch, using Beef Brown Swiss in an attempt to increase milking capacity on the cattle. Later, exotic cattle were imported from Canada. In the 1980's, bred heifers were added to the ranch line, and the 90's saw the addition of Black Gelbvieh bulls. Bill has used various marketing strategies, including the futures market. Diversification with farming began in the 1970's. The ghosts of homesteads past once again saw sod broken for the planting of wheat, barley, and oats. This was added to the strong hay base already in existence, consisting of alfalfa, clover and grass.

In the late 1960's Bill and Joyce were primary founders of the Baker Livestock Auction. Bill was the manager 1970-1974. They again became involved in the market when they bought Baker Livestock Auction in 1989. It became the current Baker Livestock Exchange. Bill was also among the buyers to first become involved in video sales, and currently serves on the board of directors for Producers Video of Fort Worth, Texas.

Community involvement has included various associations including 4-H leadership, school board, Stockgrowers Association, State Simmental Association, Montana Association of Grazing Districts, Montana Grain Growers Association, Custer County Conservation District, Montana Beef Council, Baker New Breeds Association, North Plains Feeder Association, Fort Keogh Advisory Board, and... it must be mentioned... served as Mayor of Ismay.

Once the King of the Slide Rule, Bill has been hog-tied and prodded into the computer age. He still can be found with a yellow tablet in hand, however, and remains faithful to the use of his heirloom turn-of-the-century transit. He enjoys pithy quotations, and has been known to spout occasional Latin. His special love of marketing has kept this grandfather of eleven consistently busy. He has earned his spurs through the survival of hard winters, green horses, drought, cattle prices, army cutworms, over-zealous motorcycles, Russian knapweed, beaver dams (damn beavers!), predators, grasshoppers, and a close call with an auger. It is fitting that the last year of this century will find Fort Keogh honoring this man who was a pioneer in his generation. Living through and being part of the agricultural revolution, Bill has embraced many changes. He has been willing to implement "cutting edge" ideas.

Bill's respect for education and love for challenges has netted a varied and productive life. With the hoopla and hype as the new century dawns, you'll probably find Bill ... with his ear pressed to the phone.

W. Carter Snell, Producer of the Year
Fort Keogh Open House June 1999

Producer Recognition Award

W. Carter Snell was born January 27, 1922, at Miles City, Montana, at the Darcey Hospital. He attended school from the first grade through high school, graduating May 24, 1939. He then went on to attend Helena Aeronautics School from 1939 to 1940, going on to Carroll College in the fall of 1940 through 1941. The spring of 1942, he moved to Fort Morgan, Colorado, to take a job on an Army contract at Pilot=s Pre-glider Training School.

In 1943, Carter moved to Fort Collins, Colorado, and took a job with Massey Flying Service as an aircraft and engine mechanic. They had a flight school for the Army Air Corp. He set up his own parachute loft and packed chutes for them and contracted to pack parachutes with United Airlines out of Cheyenne.

When the army contract was over, Carter returned to Miles City to enlist in the Navy; the Government said no to his enlisting as the FAA wanted him to stay in Civil Aviation. The draft board also said no to Carter=s serving in the service for the same reason, but six months later finally accepted him into the service. He was sent to Sand Point, Idaho, and then on to Norman, Oklahoma, to the Naval Air Technical training Center where he was an honor graduate. He was discharged from Jacksonville in February 1946.

In June of 1944, he married Hariette Wetzler in the Episcopal Church in Miles City, Montana. Together they had two children, Charles and Diane. They lived in Greely, Colorado, where Carter worked at an airport until moving back to the Miles City area in the fall of 1947. Carter worked in a seed-cleaning warehouse until the spring of 1948 when he moved to the Mispah AHerrin Place@ working for Nora Wiley. Nora sold out to John Scott and the Snells purchased a ranch in the North Country at Jordan and moved once again in March 1951.

Carter has raised both cattle and sheep. He started out with Herefords and was interested in selective breeding and started a record of performance system in 1952 with the cattle. The records led to a cross-breeding with Black Angus in the late 1950's. Then in 1968, artificial insemination led to the first Simmental cross calves in the spring of 1970. As the performance industry began to be noticed more, and the advent of computers, sire selection took some meaning. The 1952 steer calf crop averaged 504 pounds - calving started April 5, to sale weight December 2 in

Miles City. The indexing and subsequent selection began to show results. By 1975, with sale date cut back to November 1, the average was about 560 pounds. By 1990, the sale weight was 630 pounds.

Organizations Carter belongs to are: Elks, Montana Stockgrower=s Association, Miles City Club, Montana Beef Performance Association, American Hereford Association, American Angus Association, American Simmental Association, Montana Simmental Association, National Cattlemen=s Association, and is a 4-H leader for the Crow Rock Coyotes 4-H Club.

Carter has served on the Eastern Montana Industries board, Advisory committee at Fort Keogh, Board of Directors for the Montana Stockgrowers Association, and the Livestock Industry Laboratories Study Committee which he chaired for 5 of the many years he served on it. He has also served on the Montana Stockgrowers Animal Health Committee as well as chairing it for several years.

In 1997, Carter sold his ranch at Jordan, retiring to Miles City where he has taken up golf and works diligently on his computer in his spare time. He is still actively serving on boards in order to keep up with his avid interest in the ever changing livestock industry.

A. Rangeland Productivity

Rangelands are lands where the dominant vegetation is a mix of grasses, forbs, and shrubs that are managed as a natural ecosystem. These lands occupy nearly 50% of the world's land surface. This includes about 150 million acres of the Northern Great Plains.

Management of rangelands for agricultural purposes (i.e., grazing) is challenging due to three major factors. The first is the presence of a wide array of plant species. Secondly, great variation exists in productive capacity over time and space due to climatic variability and to differences in soils and terrain. Lastly, the extensive nature of rangelands poses a management challenge.

As a result of the complex nature of rangeland, successful management must include practices that reduce ecological and economic risks. To successfully meet this challenge, it is important that we understand the interaction effects of both abiotic (e.g., climate, atmospheric gases, and soils) and biotic (e.g., grazing) factors on quantity and quality of herbage produced.

Climate Diagram - Miles City, Montana

M.R. Haferkamp

Problem: Research conducted across the Great Plains has shown precipitation and temperature are the main factors affecting plant growth and development. Interpretation of research findings to aid in management decisions is often difficult without adequate information relative to range sites, soils, plant species, temperatures, and precipitation. We are fortunate to have long-term environmental data for some locations such as Miles City, Montana.

Procedures: We have constructed a Climate Diagram for Miles City, Montana, using data from a 96-year period (1900 to 1995). Included are (A) elevation, (B) mean monthly precipitation (mm), (C) mean monthly temperature (^oC), (D) mean annual precipitation (mm), (E) mean annual temperature (^oC), (F) average monthly minimum temperature less than 0^oC, and (G) absolute monthly minimum temperature less than 0^oC.

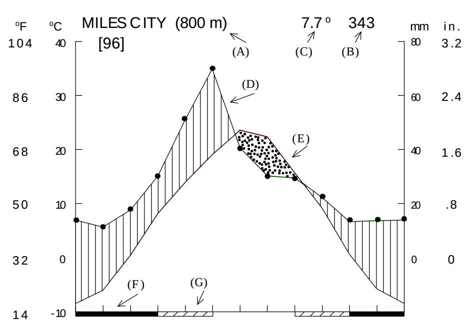


Figure 1. Mean monthly precipitation (mm) (dotted solid line) and temperature (^oC) (solid line) for 96-year period indicate mesic spring, early summer, and fall periods (vertical lines) interrupted by late summer and early fall drought (dots).

Findings: A plot of mean monthly precipitation and mean monthly temperature on a graph with unique y-axes (one division = 10^oC = 20 mm) shows wetter (mesic) (vertical lines) and drought (dots) periods for this location. Mesic periods occur when precipitation values exceed temperature values, January, February, March, April, May, June, October, November, and December, and drought periods occur when temperature values exceed precipitation values, July, August, and September. Mesic is defined as, an environment with a balanced supply of water, and drought is defined as an extended period of dry weather, especially one injurious to plants.

The diagram clearly shows maximum precipitation occurs during May and June. Greater than 20 mm (.8 inches) occurs during April, July, August, September, and October, and less than 20 mm (.8 inches) occurs during January, February, March, November, and December. Monthly average temperatures are warmer than 20^oC (68^oF) in July and August. Average minimum temperatures are below freezing in January, February, March, November, and December. Absolute minimum temperatures are below freezing in April, May, September, and October, or in other words, freezes often occur during these months.

When average minimum temperatures decline to below freezing (November), surface soils begin to freeze, and conversely with warming temperatures soils begin to thaw (March). Frozen soils limit the amount of water available for plant growth to that occurring during April through October. Most of the water occurring as snow will be lost to the atmosphere or through runoff over frozen soil into streams, rivers, ponds, lakes, and reservoirs. These are important sources of water for livestock and wildlife.

Forage production on ranges in the Miles City area is greatly dependent upon water stored in soil from fall precipitation and precipitation occurring in April, May, and June. Without this precipitation, we can expect a shortage of forage on ranges. Effectiveness of precipitation is often reduced by high temperatures during the more stressful months of July, August, and sometimes September. We usually do not expect a lot of plant growth during July and August. Although, summer rains may keep plants green, they are not actively growing. Low temperatures, even with plentiful soil water, restrict plant growth from October through April.

Climate diagrams allow one to compare potential periods of vegetation production among different areas. However, one has to be careful and first determine plant species composition for the areas. Remember some plant species such as western wheatgrass (cool season) grow better in cooler temperatures and others such as blue grama (warm season) grow better in warmer temperatures.

Measuring Carbon Fluxes over Northern Great Plains Rangelands

M.R. Haferkamp and R.K. Heitschmidt

Problem: The role of various ecosystems in regulating atmospheric carbon dioxide levels is a critical issue in global climate change research. After water vapor, carbon dioxide is the main gas holding solar energy near the earth's surface (greenhouse effect). Thus, it may be a major factor in climate change. It is known that carbon dioxide concentration in air has increased over time. It averaged 353 parts per million in 1990 and is expected to double in the next century. Carbon dioxide fluxes are also known to vary with solar radiation and evaporation. These factors are controlled by air temperature, vapor pressure, soil water content, and wind.

Rangelands are more than 40% of the land area in the world and USA. This includes 150 million acres in the Northern Great Plains. Although rangelands cover a vast area, few have estimated their potential role as a source or sink for atmospheric carbon. Missing too are measures of how environment and management affect this role. Rangelands are complex systems that are resource limited particularly for soil water and nitrogen. Complexity arises from their large size, extreme variation in soil and environment, and large number of plant species.

New studies are needed to learn the short- and long-term role of rangeland ecosystems in affecting atmospheric carbon dioxide levels. Goals of the proposed studies are to: 1) quantify rangeland ecosystem contributions to regulating atmospheric gases; and 2) better estimate impacts of livestock grazing rangelands.

Procedures: This study is one in a network covering Texas, Oklahoma, New Mexico, Arizona, Colorado, Wyoming, North Dakota, Montana, Idaho, and Oregon. Bowen-Ratio units have been installed on ungrazed, grazed, burned, seeded, and cultivated sites. These units measure net carbon dioxide and water vapor fluxes over large areas and components of the surface energy balance. Two experiments are being conducted at Fort Keogh.

Carbon dioxide flux at a landscape level is being monitored in the first experiment. The Bowen-Ratio unit was installed on an ungrazed silty range site. Soil properties, vegetation characteristics, and other data needed to study cause and effect in flux variation are sampled periodically.

Effects of seasonal grazing on carbon dioxide flux were estimated in the second experiment. Three treatments were imposed using sheep to graze small replicated plots. The treatments are: no grazing, grazed in mid-May, and grazed in mid-July. The study was conducted for three years (1996, 1997, and 1998). From mid-April to mid-November (weather permitting) at about 30 day intervals, data was collected. Data recorded includes: standing crop, leaf area on clipped and nonclipped plots, soil organic matter, root mass to a 11.8 inch soil depth, within-day variation in carbon dioxide concentration above 10.8 square feet of rangeland, and carbon dioxide evolved from bare soil.

Findings: Data from two replications of control plots in 1996 and 1997 in the second experiment are presented here. Sequestration and release of carbon dioxide are very dependent upon the environment (precipitation and temperature) as well as the growth stage of plants (Figure 1). Note how carbon is actively sequestered during the day when conditions are adequate for plant growth, but as the temperature rises, soils dry out, and as plants mature, the sequestration slows (Figure 2). Thus, at night and during stressful periods, loss of carbon dioxide by respiration will be greater than sequestration by photosynthesis. As ranges dried in July 1996, they began to act as a source of carbon dioxide even during the day in August (Figure 2A). Spring 1997 was dry, and this was reflected in less carbon dioxide sequestration during the spring and early summer compared to 1996, but in contrast to 1996, July rains in 1997 allowed some sequestration to continue into August (Figure 2A and 2B).

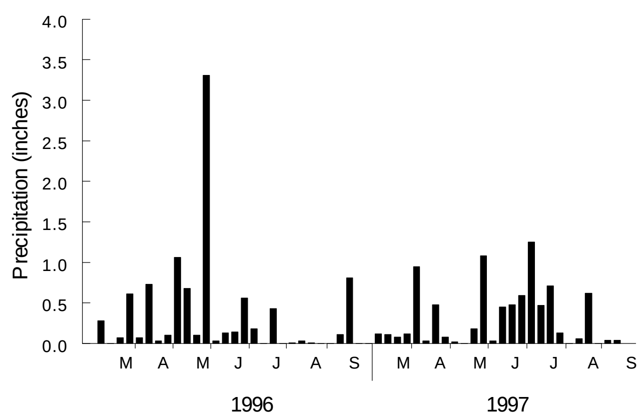


Figure 1. Precipitation for Miles City, Montana.

Future Direction: Biomass and soil samples, as well as, data from these studies are being analyzed. Information from these studies should provide improved estimates of the contribution of Northern Great Plains ranges and associated grazing practices to carbon dioxide flux and ultimately to global warming.

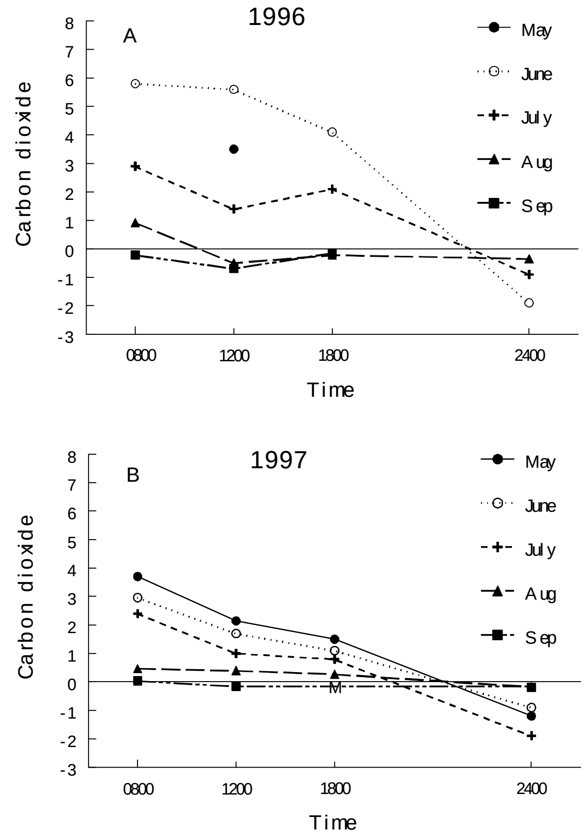


Figure 2. Carbon dioxide flux measured over two 10.8 square foot plots on ungrazed rangeland.

Relevant Publications: None to date (May 1999).

Influence of Japanese Brome on Western Wheatgrass

M.R. Haferkamp, R.K. Heitschmidt, M.G. Karl, and M.D. MacNeil

Problem: Annual bromes are notorious for competing with seedlings of perennial grasses. Several people have suggested that Japanese brome plants compete intensely with western wheatgrass plants, but this competitive effect had not been measured in the Northern Great Plains. The goal of these studies was to determine the effects of brome removal alone and brome removal and simulated grazing of western wheatgrass tillers on forage production.

Procedures: In the first study, two treatments were applied. Either all plants were left intact in a circle with a 3'8" diameter or all the Japanese brome seedlings were removed during late spring and early summer. In early July, biomass of western wheatgrass, Japanese brome, and all other vegetation was sampled to ground level in a circle with a 1'9" diameter located in the center of each plot. In the second study, the same brome removal treatments were applied, and in addition western wheatgrass tillers within the 3'8" diameter plots were clipped to ground level on May 15, June 15, or July 15 when all forage was harvested. These clipping dates coincide with potential livestock turnout dates on the Northern Great Plains.

Findings: Hand weeding Japanese brome seedlings from rangeland had two effects. Forage production of western wheatgrass was increased 240 lb/acre by late June. However, total forage production was reduced 500 lb/acre. The increase in production of western wheatgrass was apparently due to an increase in tiller density rather than plant size. Tiller weights were similar among treatments. Clipping western wheatgrass tillers before July generally reduced forage production 205 to 312 lb/acre, increased tiller density, and reduced weight per tiller of western wheatgrass accumulated during the three harvest regimes.

Removal of Japanese brome increases forage production of western wheatgrass, but decreases total forage production. These results can be expected over a wide array of environmental conditions with variable April to late June or mid July precipitation (4 to 15 inches) and variations in total current year standing crop (1,140 to 2,106 lb/acre) containing varying percentages of annual brome (22 to 51%), western wheatgrass (35 to 63%), and other species (4 to 35%).

We think we have answered the question "How much does Japanese brome impact western wheatgrass?" Now it is up to the individual producer to determine if the loss of western wheatgrass production is large enough for concern, or can they effectively manage the increased total forage production resulting from the presence of brome. One must factor in both the erratic year to year production and the rapidly declining forage quality of annual bromes.

Future Direction: We do not plan to repeat the studies in the future.

Relevant Publications: Haferkamp, M.R. 1996. Japanese brome in the Northern Great Plains, p. 100-102. *In*: J. Paterson (ed.) Proc. Governor's Conf. On the State of the Cattle Industry. 15 August 1996. Billings, MT.

Haferkamp, M.R. and M.G. Karl. 1995. Japanese brome grass on the Northern Great Plains. Western Beef Producer 1st March: 62-63, 93.

Haferkamp, M.R., R.K. Heitschmidt, and M.G. Karl. 1997. Influence of Japanese brome on western wheatgrass yield. J. Range Manage. 50:44-50.

Haferkamp, M.R., R.K. Heitschmidt, and M.G. Karl. 1998. Clipping and Japanese brome reduce western wheatgrass standing crop. J. Range Manage. 51:692-698.

Haferkamp, M.R., M.D. MacNeil, R.K. Heitschmidt, and J.A. Young. 1993. Japanese brome in the Northern Great Plains, p. 112-118. *In*: R.K. Heitschmidt, (ed.) Research and rangeland agriculture: Past, present, and future. Miles City, MT.

Haferkamp, M.R., J.D. Volesky, M.M. Borman, R.K. Heitschmidt, and P.O. Currie. 1993. Effects of mechanical treatments and climatic factors on the productivity of Northern Great Plains rangelands. J. Range Manage. 46:346-350.

Haferkamp, M.R., J.A. Young, E.E. Grings, M.G. Karl, R.K. Heitschmidt, and M.D. MacNeil. 1994. Japanese brome in the Northern Great Plains, p. 396-401. *In*: S.B. Monsen, and S.G. Kitchen (compilers) Proceedings-Symposium: Ecology and management of annual rangelands. USFS-Intermountain Research Station, Ogden, UT. Gen. Tech. Rep. INT GTR-313.

Simulated Grazing of Japanese Brome

M.R. Haferkamp, R.K. Heitschmidt, and M.G. Karl

Problem: Reducing seed production by grazing or clipping plants appears to be an effective method of interrupting life cycles of invading annual bromes in the Northern Great Plains. Heavy grazing also reduces brome production by reducing mulch which aids germination. The goal of these studies was to determine how defoliation affects above and below-ground biomass production.

Procedures: Japanese brome plants were grown from seeds in boxes maintained in a greenhouse. Plants were started in late winter. Clipping treatments were initiated in late June 1991 or early May 1992 and continued for about 60 days. Plants were either not clipped or clipped to a 3" or 6" stubble height every week or every 2 weeks. All clipped herbage was dried and weighed, and at the termination of the study, roots were washed from the soil, dried, and weighed.

Findings: In 1991, plants remained vegetative throughout. Clipping reduced tiller numbers and leaf heights. In 1992 and 1997, plants produced reproductive shoots. Clipping these plants increased tiller numbers but reduced leaf heights.

Total amount of herbage clipped was greater in 1991 than in 1992 or 1997 for the first 42 days (Figure 1). Thereafter, total clipped herbage was greatest in 1991 and 1997 and least in 1992. Total clipped herbage was greater for the first 28 days when plants were clipped at the 3" stubble height. However, by day 56 more herbage was accumulated by clipping biweekly to 6" than clipping weekly to 3". Maximum herbage was accumulated from plants clipped biweekly to 3" than from plants clipped weekly to 3" or 6".

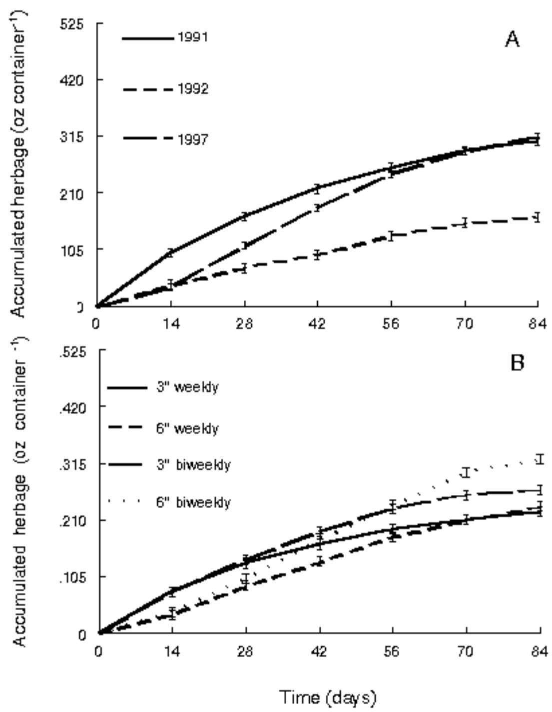


Figure 1. Accumulated clipped herbage of Japanese brome for each year and clipping intensity and frequency.

Total above-ground biomass yields were greater in 1991 and 1997 than in 1992 (Figure 2A). Total and above-ground biomass were greatest for unclipped control plants, intermediate for plants clipped to 6", and least for plants clipped to 3" (Figure 2B).

Below-ground biomass was greater for unclipped controls than all other treatments in 1991; similar among clipping treatments in 1992; and greater for plants clipped biweekly to 6" than for control plants or those clipped weekly or biweekly to 3" in 1997. Frequency of clipping did not affect above-ground, below-ground, or total biomass.

These findings suggest biomass production of vigorously growing Japanese brome plants can be reduced by frequent-intensive clipping. Thus, management of this annual brome on Northern Great Plains rangelands can affect the total amount of forage produced. Effective control of Japanese brome will be more difficult, however, because some seed was produced even with severe treatments.

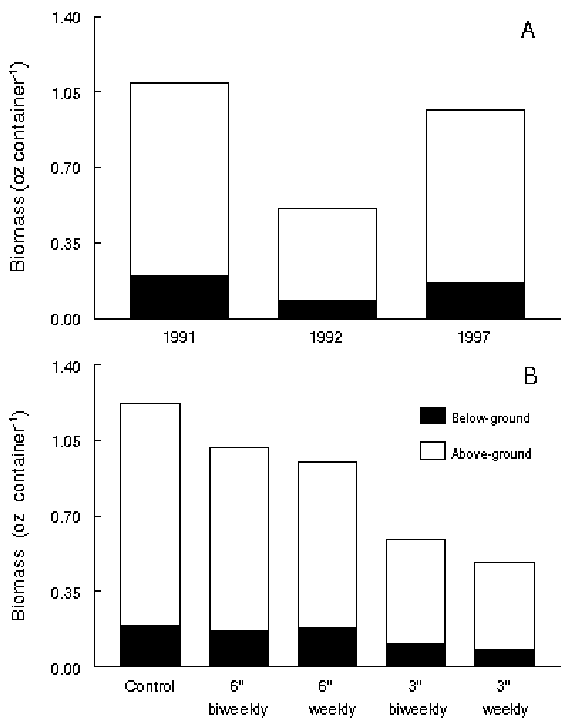


Figure 2. Above- and below-ground biomass for Japanese brome for each year and clipping intensity and frequency.

Future Direction: This study has been completed with publication of the final manuscript in 1999. Developing of grazing management tactics to reduce brome on infested ranges in the Northern Great Plains is a long-term goal.

Relevant Publications: Haferkamp, M.R. 1996. Japanese brome in the Northern Great Plains, p. 100-102. *In*: J. Paterson (ed.) Proc. Governor's Conf. On the State of the Cattle Industry. 15 August 1996. Billings, MT.

Haferkamp, M.R. and M.G. Karl. 1995. Japanese brome grass on the Northern Great Plains. Western Beef Producer 1st March: 62-63, 93.

Haferkamp, M.R., M.D. MacNeil, R.K. Heitschmidt, and J.A. Young. 1993. Japanese brome in the Northern Great Plains, p. 112-118. *In*: R.K. Heitschmidt, (ed.) Research and rangeland agriculture: Past, present, and future. Miles City, MT.

Haferkamp, M.R., J.A. Young, E.E. Grings, M.G. Karl, R.K. Heitschmidt, and M.D. MacNeil. 1994. Japanese brome in the Northern Great Plains, p. 396-401. *In*: S.B. Monsen, and S.G. Kitchen (compilers) Proceedings-Symposium: Ecology and management of annual rangelands. USFS-Intermountain Research Station, Ogden, UT. Gen. Tech. Rep. INT GTR-313.

Haferkamp, M.R. and M.G. Karl. 1999. Clipping effects on growth dynamics of Japanese brome. J. Range Manage. 52:339-345.

Effects of Mechanical Treatments and Climate on Productivity of Northern Great Plains Rangelands

M.R. Haferkamp, R.K. Heitschmidt, J.D. Volesky, and P.O. Currie

Problem: Land managers often seek ways to increase forage produced for livestock. Research conducted across the Great Plains has shown precipitation and temperatures are the main factors affecting plant growth and development. Shifts in forage production may also result from adding nitrogen, removing woody plants, and tilling the soil. Effects of these factors vary with climate, soil, slope, and post-treatment management. The goal of this study was to examine long-term effects of managerial interventions on forage and livestock production.

Procedures: Two sites were studied. One site had heavy clay and clay pan soils. The other had silty clay loam and loam soils. Dominant perennial grasses were western wheatgrass, blue grama, buffalograss, Sandberg's bluegrass, needle-and-thread, and Texas tumblegrass. Threadleaf sedge was the dominant grass-like species. Japanese and downy brome were the dominant annual grasses. Wyoming big sagebrush was the dominant shrub.

Seven treatments were established in eight 30-acre pastures at both sites in 1982 (Table 1). Wyoming big sagebrush was controlled by either mechanical chopping or spraying with 2,4-D. Fertilization was 50 lb/acre of ammonium nitrate. The range improvement machine (RIM) concurrently created variably spaced water retaining furrows on the contour with intermittent check dams. It also planted grass and legume seed, and applied fertilizer. Interseeded legumes were cicer milkvetch and Spreador II alfalfa. Forage production was estimated in all pastures just before each grazing season by harvesting current years forage to a 1-inch stubble height.

All treatments were moderately grazed in summer beginning in 1983 with three to five, Hereford-crossbred, 650 pound steers. Grazing generally continued for 90 days, but steers were removed earlier in drought years. Steers were weighed at the beginning, near mid-season, and end of each annual trial. Diet quality was

Table 1. Rangeland treatments applied in 1982 at Fort Keogh.

			Tillage		Seeding		Grazing	
Treatment	Brush Control	Nitrogen Fertilizer	Contour Furrow	RIM	Drill	Broadcast	Season Long[1]	Switch Back[2]
C(control)							X	
2				X			X	
3				X	X		X	
4	X			X	X			X
5	X			X	X		X	
6		X		X			X	
7			X			X	X	

[1] 1-herd, 1-pasture
[2] 1-herd, 2-pasture

estimated in all treatments at both sites at the beginning and end of 1987 and 1988 grazing seasons. Samples were collected from esophageally fistulated steers grazed in the early morning.

Findings: Annual variation in climatic conditions had a greater impact on forage production than any treatment (Figures 1, 2, and 3). Maximum year-to-year effect was about 1.6 times the treatment effect.

Soil tillage was the primary treatment driving increases in forage production (Table 1 and Figure 2). Increased forage production from soil tillage was not accompanied by major shifts in plant species composition (Figure 2). This finding is in contrast to most previous studies conducted in the Northern Great Plains. Usually, mechanical furrowing has increased yield of perennial or annual cool-season grasses. Western wheatgrass and annual bromes may have been so dominant before treatments were applied that their response to treatments was minimal.

Plant species responded to annual differences in climatic conditions (Figures 1 and 3). Sandberg's bluegrass tended to increase following drought. Yields of both Sandberg=s bluegrass and western wheatgrass increased when fall and spring rainfall were above average. Annual grass production was greatest in the years after tilling the soil and the drought of 1988.

Range improvement treatments tended to increase steer production (Table 2). However, treatment effects were small.

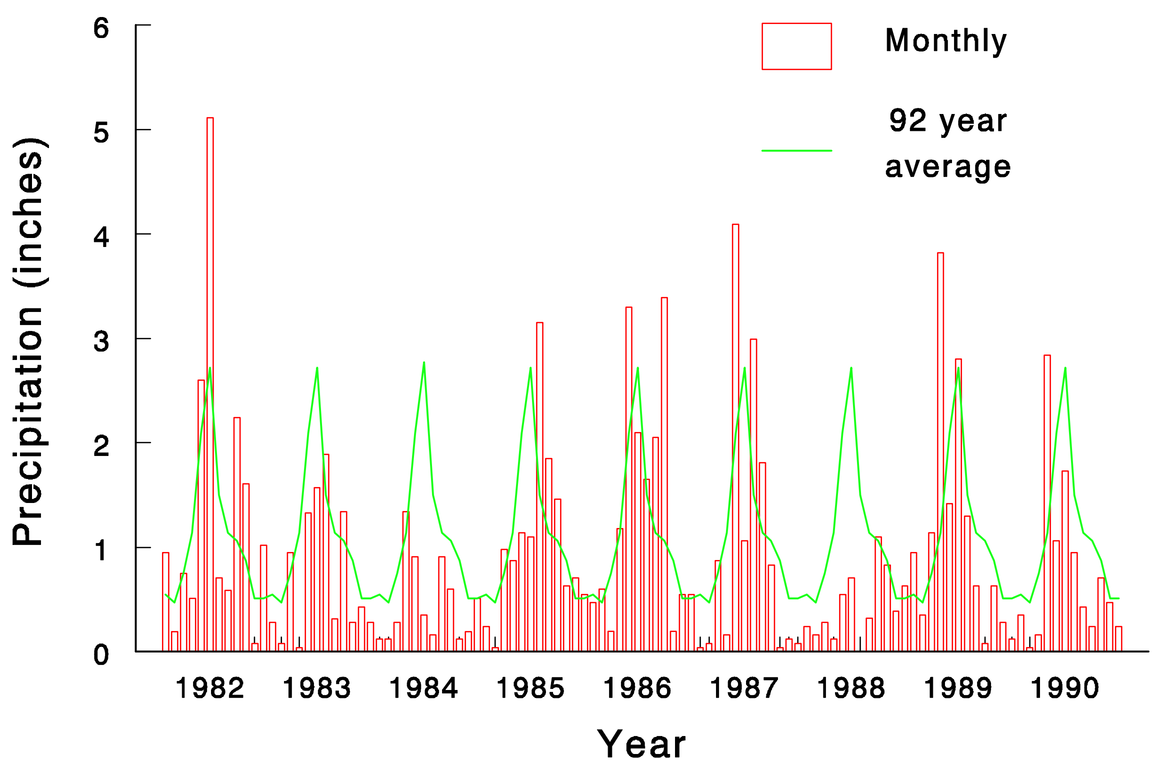


Figure 1. Actual (Jan. – Dec. 1982-1990) and long-term (92 year) average precipitation for Miles City, Montana.

Table 2. Steer performance for the seven treatments averaged across six years.

Treatment	ADG	Gain/Steer	Gain/Acre
	--------------	(pounds)	---------------
C	1.1	56	12
2	1.3	90	15
3	1.3	99	18
4	1.3	93	16
5	1.5	112	20
6	1.3	99	17
7	1.5	106	19

Steer growth was affected more by annual climatic conditions (Table 3) than treatments. Year-to-year differences in average daily gain were primarily related to amount and seasonal pattern of rainfall (Figure 1). However, differences among years in gain per acre were related to both average daily gains (Table 3) and stocking rate. Average daily gains decreased markedly as the season progressed, except in the severe drought of 1988. Diet quality was not affected by treatment. Average crude protein content of the diet varied between 1987 (9.0%) and 1988 (5.8%). Across all years, it declined from 9.6% at the beginning of the season to 5.2% at the end.

The dynamic interrelationship of environment and vegetation in the Northern Great Plains is a constant challenge for land managers. They need special skills in this region with large and rapid changes in forage production caused by periods of above- and below-average rainfall. This challenge increases as

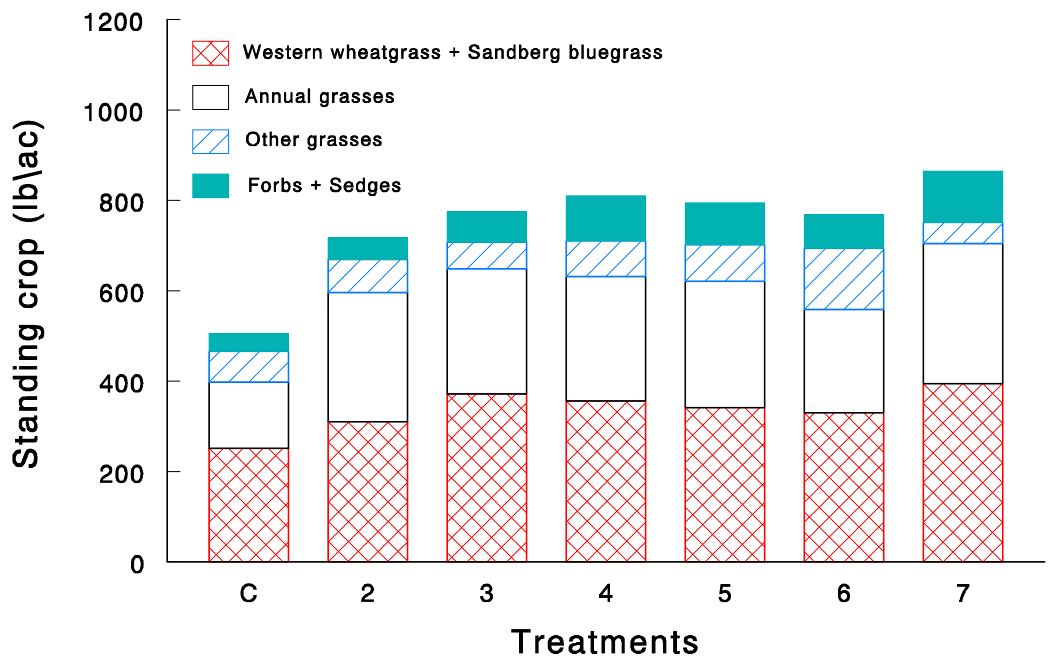


Figure 2. Current year forage production by treatment (see Table 1) averaged across two sites and eight years.

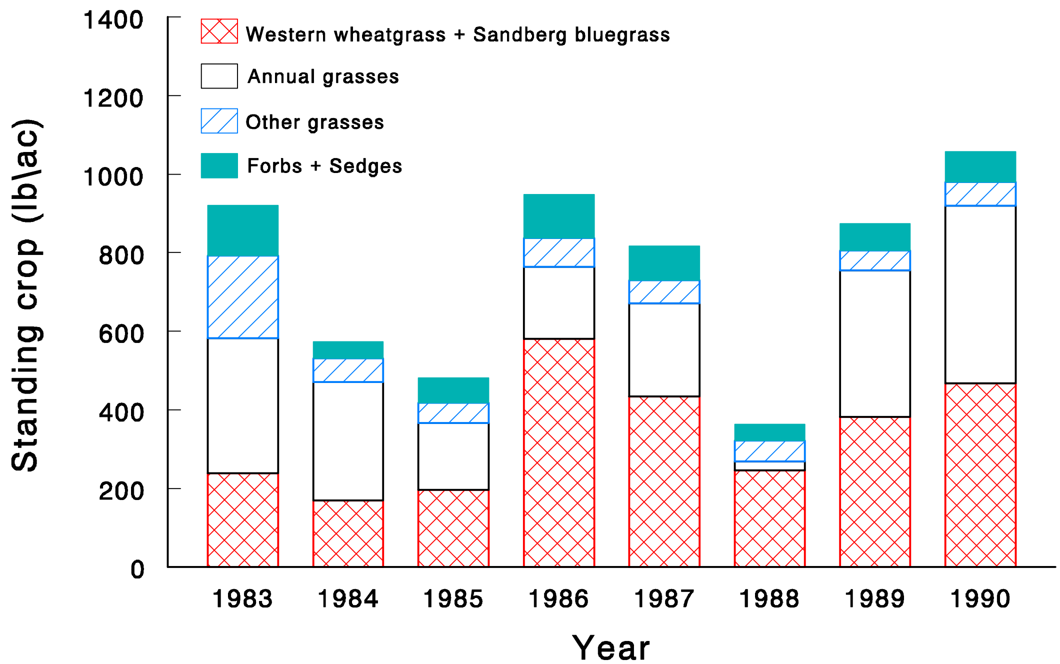


Figure 3. Current years forage production by year averaged across two sites and seven treatments (see Table 1).

annual bromes invade. Currently, they may contribute 40% of the forage produced each spring.

Table 3. Steer performance for 1983 through 1988 averaged across the treatments.

	Year					
Variable	1983	1984	1985	1986	1987	1988
	- - - - - - - - - (pounds) - - - - - - - - - - -					
ADG	1.1	1.8	1.5	1.5	1.5	1.7
Gain/steer	108	108	62	143	137	22
Gain/acre	19	19	11	24	26	3

Future Direction: Future studies will address the impact of seasonal drought and annual brome invasion on forage and livestock production.

Relevant Publications: Haferkamp, M.R., J.D. Volesky, M.M. Borman, R.K. Heitschmidt, and P.O. Currie. 1993. Effects of mechanical treatments and climatic factors on the productivity of Northern Great Plains rangelands. J. Range Manage. 46:346-350.

Haferkamp, M.R., J.D. Volesky, M.M. Borman, R.K. Heitschmidt, and P.O. Currie. 1993. Effect of mechanical treatments and climatic factors on the productivity of northern mixed-grass prairie, p. 107-110. *In*: R.K. Heitschmidt, (ed.) Research and rangeland agriculture: Past, present, and future.

Haferkamp, M.R., R.K. Heitschmidt, J.D. Volesky, and P.O. Currie. 1996. Tillage boosts range forage production. Western Beef Producer. 2nd March:12-13, 56.

Heitschmidt, R.K., J.D. Volesky, M.R. Haferkamp, and P.O. Currie. 1993. Steer performance on native and mechanically modified Northern Great Plains rangeland. J. Range Manage. 46:529-533.

Heitschmidt, R.K., J.D. Volesky, M.R. Haferkamp, and P.O. Currie. 1993. Effects of mechanical treatments and climatic factors on livestock production in the northern mixed-grass prairie, p. 110-112. *In*: R.K. Heitschmidt, (ed.) Research and rangeland agriculture: Past, present, and future. Miles City, MT.

Seed Bank Dynamics in a Northern Great Plains Rangeland

R.K. Heitschmidt, M.G. Karl, and M.R. Haferkamp

Problem: Plant species composition of grasslands varies over both time and space. Plant mortality and natality are basic processes that control rate and direction of changes in composition. It is hard to predict these changes without knowing about such factors as availability of seeds and seed germination and seedling establishment. The goal of this study was to describe seed inputs, storage, and depletion on an ungrazed rangeland.

Procedures: The study was conducted on a gently sloping, ungrazed, clayey range site. Vegetation was dominated by western wheatgrass, blue grama, and Japanese brome. Other important species were needle-and-thread, prickleypear cactus, and winterfat. Each of the three 1/10 acre areas was sampled on up to 21 dates from September 1991 to July 1993. Data collected included standing crop, number of seedlings, and number of aerial born seeds.

Findings: Herbage standing crop ranged from about 1230 lb/acre in February to 3800 lb/acre in June. Maximum standing crops, over the entire year, for dominant species were: western wheatgrass, 1100 lb/acre; blue grama, 1475 lb/acre; Japanese brome, 450 lb/acre; and prickleypear cactus, 850 lb/acre.

Peak density of aerial seeds was generally reached in June at time of peak standing crop. Dominant species groups, relative to number of seeds/ft^2, were: perennial grasses, 375; annual grasses, 1150; and forbs, 125. Estimated peak seed densities (number/ft^2) for the dominant species were: western wheatgrass, 2; blue grama, 10; Japanese brome 975; and prickleypear cactus, 25.

Seedling densities varied largely as a function of abundance of seeds and climatic conditions. For example, the range in density from September 1991 to July 1993 was: western wheatgrass, 0; blue grama, 0-2; Japanese brome, 0-200; and prickleypear cactus 0-27. Maximum densities were obtained in the fall of 1991 when precipitation was abundant. Seedling densities the remaining 16 months of the study were near zero for all species except Japanese brome which had a secondary peak in the fall of 1992 of about 70 seedlings/ft^2.

The results of this study show there is an abundant seed reserve for continued propagation of annual grasses, particularly Japanese brome, in these grasslands. The data also provide evidence that propagation of perennial grasses on this rangeland depends largely on successful vegetative reproductive processes, particularly with regards to western wheatgrass.

Future Direction: An inventory of soil and litter seedbanks in these same areas will be conducted. Potential impacts of grazing and drought on rangeland seedbanks are also of interest. Monitoring seedbank dynamics continues in the rainout shelter drought/grazing treatments described elsewhere in this report. This information will aid in predicting long-term changes in plant species composition of these grasslands.

Relevant Publications: Karl, M.G., R.K. Heitschmidt, and M.R. Haferkamp. 1993. Rangeland Seed Banks, p. 119-122. In: R.K. Heitschmidt (ed.) Research and Rangeland Agriculture: Past, Present and Future, Miles City, MT.

Karl, M.G., R.K. Heitschmidt, and M.R. Haferkamp. 1993. Seedbank dynamics of native Northern Great Plains rangelands. 46th Ann. Meeting Soc. Range Manage. Albuquerque, NM. #219.

Karl, M.G., R.K. Heitschmidt, and M.R. Haferkamp. 1994. Cattle feces and plant distribution. I. Seedling emergence and establishment from a transient seed bank. 47th Ann. Meeting Soc. Range Manage. Colorado Springs, CO. p.26.

Karl, M.G., R.K. Heitschmidt, and M.R. Haferkamp. 1994. Cattle feces and plant distribution. II. Effects on vegetation and soil seed bank. 47th Ann. Meeting Soc. Range Manage. Colorado Springs, CO. p.74

Karl M.G., R.K. Heitschmidt, and M.R. Haferkamp. 1994. Sexual reproductive functioning of a northern mixed-grass prairie community containing Japanese brome (Bromus japonicus). 14th North Amer. Prairie Conf., Manhattan, KS.

Mineral Dynamics of Forages During the Growing Season

E.E. Grings, M.R. Haferkamp, R.K. Heitschmidt, and M.G. Karl

Problem: Devising nutritional management strategies for grazing livestock requires understanding dynamics of a broad range of forage nutrients. Protein and energy are two nutrients commonly deficient for at least part of the year. Potential mineral deficiencies are also often reported. Mineral content of plants varies with soil fertility, plant species, stage of plant maturity, availability of water, and tissue age. There is limited information on mineral content of forages of the Northern Great Plains. Other researchers have suggested realistic bounds for mineral levels of livestock diets could be determined by comparing live tissue and whole plant mineral content. Eating only live tissue would provide a maximum mineral concentration while eating whole plants would provide a minimal level of minerals. The goal of this study was to evaluate variation in mineral concentrations in major forages growing in the Northern Great Plains.

Procedures: Plant material was sampled from two soils types (Eapa loam and Sonnet silty clay). Estimated range condition was good on the Eapa loam soil and fair on the Sonnet silty clay soil. Sampling was done in July, August, and September 1991, April, June, July, August, and September 1992, and April

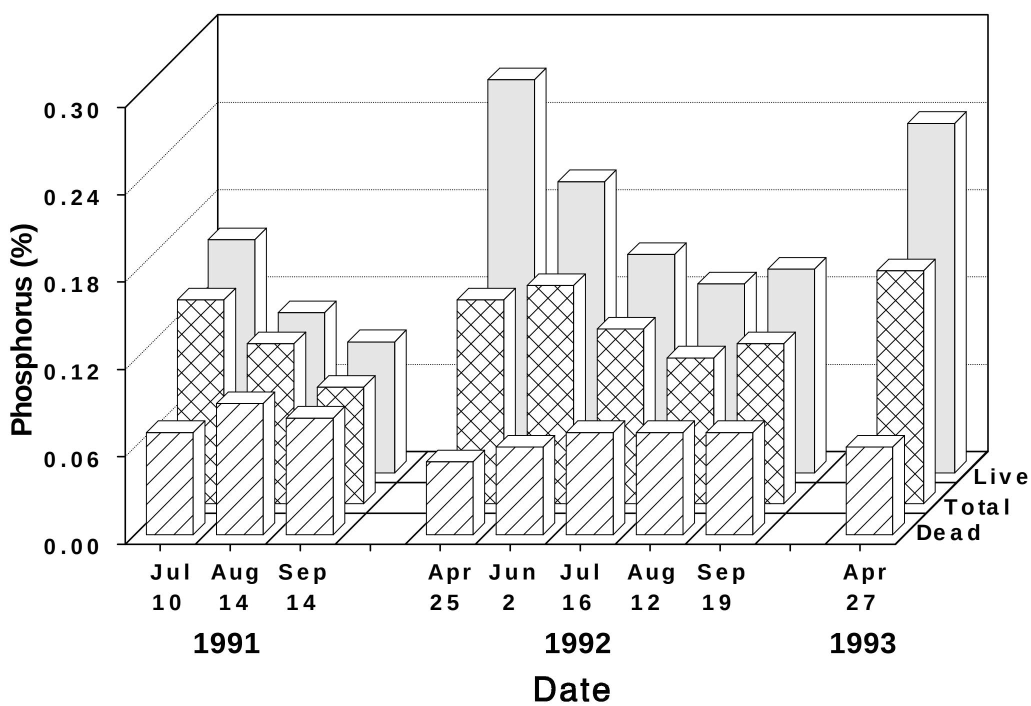


Figure 1. Live, dead, and whole plant phosphorus concentrations (% of dry matter) for western wheatgrass on 9 dates.

1993. Herbage was sorted by species grouping and by live and dead tissue classes. Analyses of plant material included calcium, phosphorus, magnesium, potassium, sodium, zinc, copper, manganese, and molybdenum.

Findings: In western wheatgrass and annual bromes, zinc and all macrominerals except sodium were greater in live than in dead tissue. Live tissues of all other species groupings had greater amounts of phosphorus and potassium than dead tissue. Live tissue magnesium content was greater than dead tissue content for other cool-season and warm-season grasses. Manganese content was greater in live than dead annual brome tissues. However, copper content of dead tissue was greater than in live tissue. Dead sedge tissue also had higher calcium content than live tissue.

Soil type affected several nutrients. However, these effects were partly related to effects on the make-up of species groupings and on live:dead ratios.

Nutrients that were most likely to be in quantities less than that recommended for beef cattle were phosphorus, potassium, sodium, zinc, and copper. We conclude that the relative amount of live and dead was a major influence on whole-plant nutrient content for all macrominerals except sodium. This was less apparent for the trace minerals. The relative amounts of live and dead tissue may be used to assist in determining mineral levels in cattle diets, especially for phosphorus and potassium.

Future Directions: This project was completed.

Relevant Publications: Grings, E.E., M.R. Haferkamp, R.K. Heitschmidt, and M.G. Karl. 1996. Mineral dynamics in forages of the Northern Great Plains throughout the growing season. J. Range Manage. 49:234-240.

Vegetation and Livestock Respond to Brome Removal with Atrazine[1]

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

Problem: Japanese and downy bromes, introduced annual-weedy grasses, occupy thousands of acres of Northern Great Plains' rangelands. Although bromes produce large amounts of nutritious spring forage, they can have short-term negative impact on perennial forage species and performance of grazers. Annual forage production on brome-infested rangelands changes greatly from year to year with variations in rainfall and soil nitrogen. Forage quality of annual bromes is comparable to perennial grasses at similar growth stages, but annual bromes mature quicker than perennial grasses. The goal of this study was to determine the impact annual brome removal with a chemical herbicide, atrazine, had on forage production, forage quality, and livestock production on Northern Great Plains' rangeland.

Procedures: Soils at the study site on Fort Keogh are a mixture of heavy clays and clay pans. Topography is gently sloping (<2%). Vegetation is dominated by western wheatgrass, blue grama, Sandberg bluegrass, sand dropseed, and Japanese brome. Threadleaf sedge is the dominant grasslike species. Dandelion and salsify are the dominant forb species.

Two brome reduction treatments were randomly assigned to six 30-acre pastures in 1992. Treatments were (1) brome undisturbed and (2) brome reduced with atrazine applied to dormant vegetation in November 1992 and 1993 at 0.5 lbs/acre.

Each pasture was stocked annually with 8 Hereford crossbred steers. Pastures were grazed season-long from mid-May until mid-September 1993 and 1995, but due to limited forage grazing was terminated in mid-August 1994. Initial weight of steers averaged 725 lbs in 1993, 602 lbs in 1994, and 600 lbs in 1995.

Forage biomass and steer weights were determined at the beginning, about every 30 days, and at the end of each annual trial. Forage biomass was clipped by species or species group to ground level in a key area located near the center of each pasture.

Findings: Forage biomass samples collected during the growing season reflected not only brome removal, but also, the influence of precipitation, temperature, and grazing. In several instances response of forage crop to brome removal varied with date of sampling as well as year of the study.

Sedges, annual grasses, total green biomass, and total biomass (including standing dead) were affected by brome removal. Sedges were reduced from 14 lbs/acre with brome to a trace with brome removed. Other perennial grasses, forbs, and standing dead were not affected by brome removal.

Response of annual grasses, total green biomass, and total biomass to treatment varied both with year and date (Figure 1). Brome removal reduced annual grasses on each sample date in 1993 and 1995 but not 1994. Total green biomass and total biomass were reduced by brome removal in June and July 1993, August 1994, and July 1995.

Response of forage crude protein percentages to brome removal varied with year and date, except for standing dead that contained 5% with brome and 6.3% with brome removal. Lack of forage prevented analysis of crude protein data for downy brome, Sandberg bluegrass, sedge, other annual grasses, and other perennial grasses.

Brome removal increased crude protein in western wheatgrass in 1993 and 1994, but not 1995 (Figure 2A), and the difference between treatments decreased from 4% in May to 1% in August (Figure 2B). Brome removal increased crude protein in Japanese brome in 1993 but not in 1995 (Figure 3).

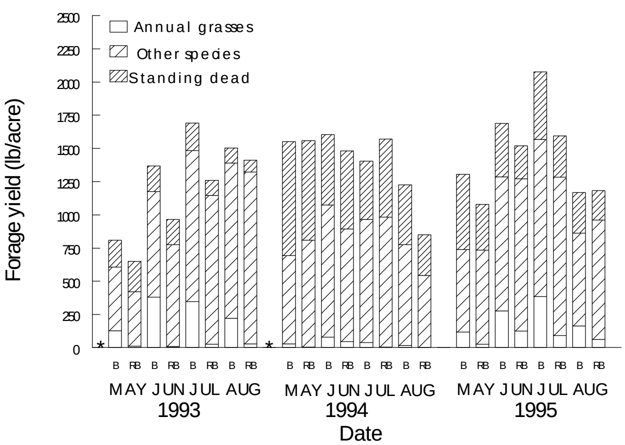


Figure 1. Forage yield for annual grasses, other green biomass, and standing dead for brome removal treatments on 12 dates. * Denote periods when atrazine was sprayed on pastures.

Brome removal increased crude protein percentage of forbs in 1993, but not 1994 or 1995, (Figure 4A) and in May, June, and August, but not July (Figure 4B). Brome removal did not affect crude protein percentage of blue grama.

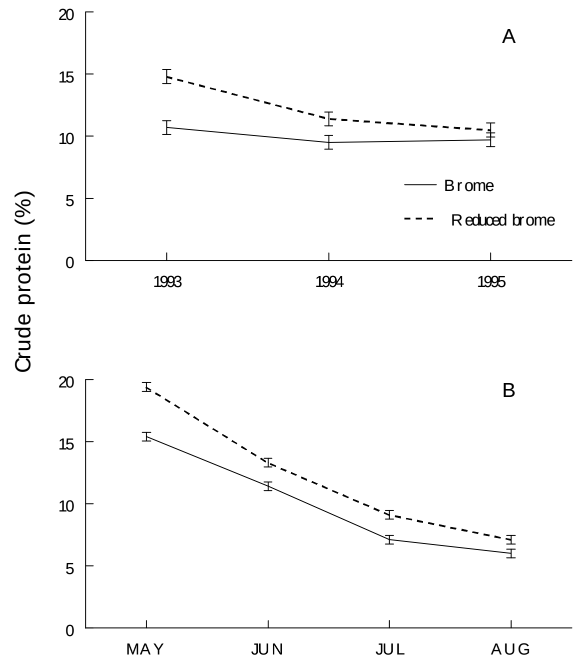


Figure 2. Crude protein concentration for western wheatgrass for brome removal treatments for 3 years (A) and 4 dates (B).

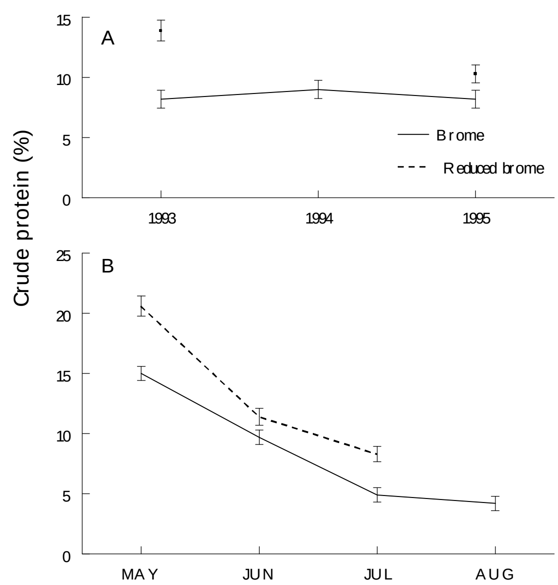


Figure 3. Crude protein concentration for Japanese brome for brome removal treatments for 3 years (A) and 4 dates (B).

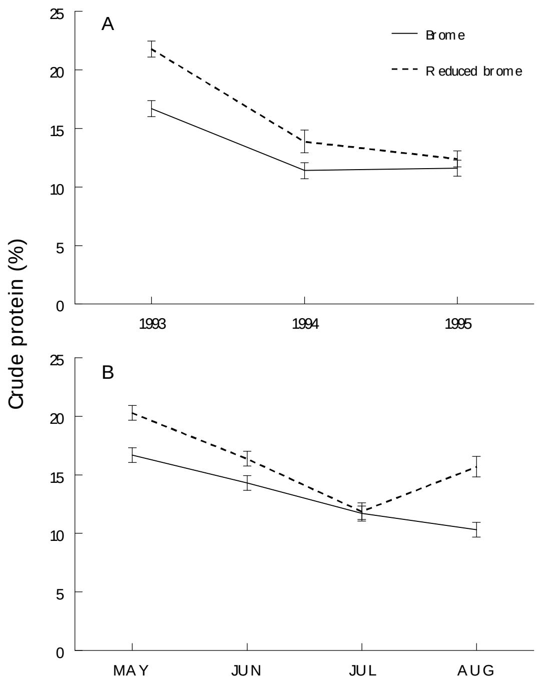


Figure 4. Crude protein concentration for forbs for brome removal treatments for 3 years (A) and 4 dates (B).

Steer gains were affected by brome removal whether expressed as gain per acre or gain per animal (Table 1). Gains were consistently increased during the intervals May to June, June to July, July to August, and August to September (Table 1).

Table 1. Steer gains for brome removal treatments averaged across dates and years.

Treatment	lb/acre	lb/head	lb/head/day
Brome	15.4	56.2	1.96
Brome reduced	18.0	66.2	2.25

The numerous interactions with year and date clearly show the impact environment has on forage and livestock production in the Northern Great Plains. Above average precipitation in 1993, produced an abundance of forage, that was too much for steers to consume during the grazing season. Thus forage increased through summer, and forage quality remained relatively high. Increased growth also provided large amounts of standing dead in fall 1993 and during 1994. This large amount of standing dead present in fall 1993 may have reduced the effectiveness of atrazine applied in November 1993 and may have reduced the choice of forage available for steers grazing in summer 1994.

Findings clearly show forage quality was improved by brome removal, and this increase in quality probably improved livestock performance. However, we do not know how much of the increase in forage quality was due to reduction of brome and how much of the increase was influenced by the affect of sublethal doses of atrazine on perennial grasses. Sublethal doses of atrazine reportedly increase nitrogen concentration in some perennial plants. In another study, we also found slight but significant increases in crude protein percentages of western wheatgrass forage (8.3 to 9.0%) when brome seedlings were removed by hand before 15 May 1995, and forage was harvested in mid-July, whereas Currie et al. (1987) found only slight, nonsignificant differences in crude protein concentrations in forage sampled in early July from a blue grama and western wheatgrass dominated community sprayed 1 to 2 years earlier with atrazine at 0.54 lb/acre. Forage from sprayed plots contained 9.2% protein in 1983 and 14.6% in 1984. In comparison, forage from non-sprayed controls contained 8.6% protein in 1983 and 14.2% in 1984.

Future Directions: This completes this phase of Japanese brome research. Two manuscripts will be submitted for publication in the Journal of Range Management in 1999, and updated reports will be written.

Relevant Publications: None at this time.

[1] We used atrazine (then labeled for rangeland use) to reduce brome in several pastures. The rangeland label was removed from atrazine in the late 1980's. As of the date of publication, manufacturers have not yet applied to the Environmental Protection Agency to relabel atrazine, a restricted-use pesticide for agriculture, for use on rangelands in the United States.

B. Management Strategies for Grazing Livestock

The Northern Great Plains are subject to wide environmental variations both within a single year and among years. This variability poses a challenge to those beef cattle producers. Periods of limited forage quality or quantity exist due to low temperatures (winter) or limited water (late summer and fall). Strategies can be devised to overcome these limitations to animal production. Programs may include the use of complementary forages, provisions of supplemental feed, the use of cattle whose needs match the environment, and variations in timing of resource use.

Besides the effect of management on the productive efficiency of livestock, the impacts on ecological health must be evaluated. Ecological time frames are long and studies to evaluate ecological impacts are, therefore, quite prolonged. One important facet of government-sponsored laboratories, such as Fort Keogh, rests with the ability of these laboratories to make long-term commitments to this type of research.

Impacts of Various Livestock Grazing Strategies on Northern Great Plains Rangelands

R.K. Heitschmidt and M.R. Haferkamp

Problem: Impacts of livestock grazing on Western U.S. rangelands are the subject of much debate. Unfortunately, this debate is often fueled more by emotion arising from limited scientific understanding of rangeland ecosystems than facts. Quite frankly, quantitative data clearly detailing both short- and long-term impacts of livestock grazing on rangeland "health" are scarce. There is also a dire need for research areas of varying ecological condition so as to provide researchers with the opportunity to explore how rapidly rangelands in the Northern Great Plains can shift from one ecological condition to another and what the effects of such shifts are on sustainable livestock production. The broad goal of this study is to quantify the short- and long-term (>20 years) impacts of cattle grazing on Northern Great Plains rangelands.

Procedures: Four large livestock exclosures have been established. Size of exclosures range from about 20 to 80 acres. Within each exclosure, herbage standing crop is estimated periodically. In addition, there are selected study sites in adjacent grazed areas for comparison purposes. Both grazed and ungrazed study sites are sampled in the same manner. Thus, "real life" grazing effects on these rangelands can be compared with no grazing.

In addition, an intensive study has been initiated to quantify the effects of seven different grazing strategies on these rangelands. There are six moderately stocked treatments and one heavily stocked treatment. All treatments are simulated in twice replicated, 15 acre pastures. Treatments are:

A. Moderately stocked

1. **Three (3) pasture, one herd, twice over rotation**. Grazing begins each year on June 1 and ends October 12. In this system, every pasture is initially grazed every year for 15 days and then rested for either 30, 45, or 60 days, depending upon whether the pasture is the first, second, or third pasture grazed during the year. Following this period of rest, each pasture is then grazed again for 30 days. To prevent grazing every pasture at the same time each year, the rotation is begun each year in a different pasture, that being the last pasture grazed the year before. Thus, a pasture is only grazed/rested at the same time every fourth year.

2. **One pasture (1), one herd, season long grazing**. This pasture is grazed continuously from June 1 to October 15.

3. **Twelve (12) pasture, one herd, high intensity, low frequency.** Each pasture is grazed every other year from June 4 to June 27 (i.e., 24 days). Period of rest is 730 days (i.e., approximately two years). The simulated grazing season is from June 1 to October 15.

   This treatment uses high use grazing (HUG) tactics to the extreme. The idea behind HUG tactics is that all plants, both preferred and non-preferred, will be defoliated during each grazing period. Thus, HUG tactics are hypothesized to do more "harm" to non-preferred than preferred plant species. This is because the preferred species have evolved under conditions of frequent defoliation and the non-preferred species have not. Thus, if both are defoliated it is assumed that the competitive advantage during the two-year rest period after grazing will favor the defoliated preferred rather than the defoliated non-preferred species.

4. **Fifteen (15) pasture, one herd, short duration grazing.** In this system, each pasture is sequentially grazed for 3 days and rested for 42 days. The simulated grazing season is from June 1 to October 15.

   This treatment uses high performance grazing (HPG) tactics. In contrast to HUG tactics, HPG tactics cause greater numbers of preferred than non-preferred plants to be defoliated. However, because of the short grazing period, it is perceived that intensity of defoliation of the pre-ferred plants is much less in HPG than HUG systems. Thus, it is reasoned that preferred plants will recover rapidly during the 45-day rest period thereby allowing them to aggressively compete against the undefoliated, non-preferred plants for critical resources (e.g., water and nutrients).

5. **Three (3) pasture, one herd, winter rotation.** Grazing season is from Oct. 13 until March 21. In this system, the herd grazes each of the three pastures once during the dormant season for 57 days. As in treatment 1, the first pasture grazed each year rotates among pastures so that the pasture grazed first is the one grazed last the next year and grazed second the year thereafter. Thus, each pasture is only grazed at the same time of the year every third year.

6. **One (1) pasture, one herd, spring calving pasture.** This pasture is grazed continuously from March 21 until June 1 every year. Although many ranchers may calve in the same pasture(s) each year, research quantifying the impacts of this practice on plant species composition, long-term herbage production, etc. is lacking.

The combination of treatments 1 through 4 in combination with treatments 5, and 6 make up a year-round management system that, among others, may be appropriate to cow-calf production.

B. Heavily stocked

Beat it into the ground. This treat-ment is designed to "push" this Northern Great Plains rangeland ecosystem to its limit. It is excessive and intended to move the system as rapidly as possible away from anything "normal" to learn what the limits of grazing stress are, whether this system will break, how rapidly it can recover, etc.? In this treatment, grazing will be as intense and frequent as possible.

Findings: The first two years of the exclosure study show no differences in plant species composition between the ungrazed and grazed study sites. However, standing crop is greater inside than outside the exclosures.

Grazing trials were begun in the spring of 1997. Thus, no results from them are available, yet.

Future Direction: These studies are designed to continue indefinitely. This is appropriate because effects of grazing may only become apparent over a long time (>20 years).

Relevant Publications: None to date (July 1997).

Dietary Composition of Grazing Cattle of Varying Age and Sex

E.E. Grings, R.K. Heitschmidt, R.E. Short, and M.R. Haferkamp

Problem: Strategic supplementation of nutrients requires an estimate of the quality of the diet at any point in time. Animals of differing age and sex classes have differing nutrient requirements and may also make different dietary choices while grazing. Differences in diet selection between young, suckling ruminants and older animals have been observed. Limited differences in diet selection between mature cows and 2-year-old steers were observed on semi-desert range with the greatest differences occurring in fall. Differences in diet selection between sexes may be greater during periods of limited forage availability. The goal of this study was to evaluate the influence of animal age and sex on botanical and chemical composition of cattle grazing Northern Great Plains' rangeland.

Procedures: Esophageally cannulated suckling heifer calves, yearling heifers, mature cows, and mature steers were used to collect representative diets. 1994. Samples were collected each month from June through October during each of 2 years. Two vegetatively similar native rangeland pastures of 210 and 222 acres were grazed at a density of 10.9 acres per steer from mid-May to mid-September 1993 and from mid-May to late-August.

Collection bags were placed on cattle at 7 a.m. and they were allowed to graze for 30 to 45 minutes. After drying, samples were divided with one-half used for analysis of crude protein and *in vitro* organic matter digestibility and the other half used for microhistological analysis for botanical composition.

Forage availability on 2 representative range sites was determined during the same week as diet collections. Forage samples were composited by range site and analyzed for crude protein and *in vitro* organic matter digestibility.

Findings: Precipitation patterns differed between the 2 years of study altering the quality of available forage in the 2 years (Figures 1 and 2). Overall animal types, diet quality was greater in 1993 than 1994 due to greater precipitation throughout the summer. Diet quality declined steadily throughout the 1993 growing season (Figures 1a, 2a.), whereas, in 1994,

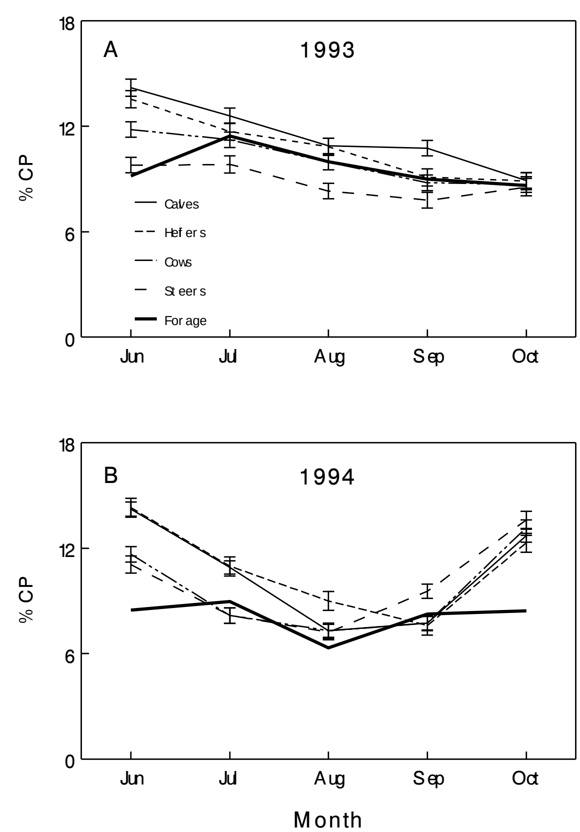


Figure 1. Dietary crude protein (a, b; organic matter basis) and during 2 growing seasons for 4 classes of cattle. The solid line represents protein concentration of forage available in 2 range sites at the time of diet sample collection.

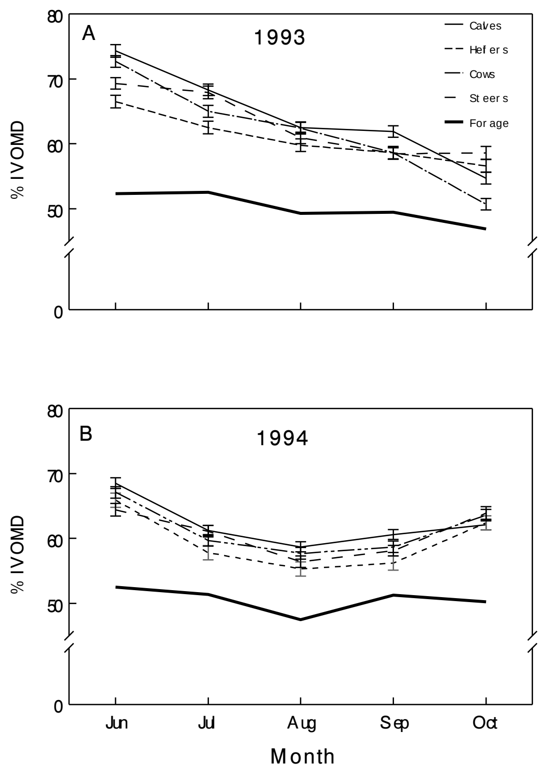


Figure 2. *In vitro* organic matter digestibility (a, b; organic matter basis) during 2 growing seasons for 4 classes of cattle. The solid line represents the *in vitro* organic matter digestibility of forage available in 2 range sites at the time of diet sample collection.

quality fell sharply between June and September and then increased in October after fall rains (Figures 1b, 2b). Crude protein levels of available forage were below that of all selected diets in June and October of 1994, indicating strong diet selection at these times. *In vitro* organic matter digestibility of available forage was always well below that of selected diets.

Although seasonal trends in diet quality were observed for all animal types, dietary crude protein exhibited an interaction among animal age class, month, and year. In 1993, diets were of lower quality for steers than other classes of cattle in all months except October, whereas in 1994, cow and steer diets were similar in crude protein in all months except September. This emphasizes the caution needed in using animals of varying age and sex classes in evaluating diet quality.

Western wheatgrass accounted for an average of 56% of all diets. Shrubs, averaging 18.8%, were the next greatest component of the diet. Shrubs in the diet included winterfat, greasewood, shadscale, western snowberry, Wyoming big sagebrush, and fringed sagewort. Forbs were a minor component of the standing crop and were, therefore, a minor component of the diet in this vegetation type.

While general trends in diet quality throughout a growing season may be somewhat similar among classes, absolute values may be quite different. If mature steers had been used to estimate diet quality for either calves or yearlings in June of 1993, crude protein would have been under-estimated by 3% compared to using calves or yearlings to collect diet samples. We might have suggested differing management strategies for these cattle based upon these erroneous results.

Alterations in botanical composition of diets of differing age and gender classes of cattle can result in variations in chemical composition of those diets. Therefore, animals used to obtain diet quality estimates on rangelands with diverse botanical composition should be of similar gender and age as animals whose performance is being measured. This caution should be exhibited especially when forage availability is low, botanical diversity is high, and(or) results are being used to calculate nutrient intakes.

Future Directions: We continue to collect diet quality estimates for our research using the appropriate animal class. We currently do not have plans for further research on comparing diet quality of animal classes.

Relevant Publications: Grings, E.E., R.K. Heitschmidt, R.E. Short, and M.R. Haferkamp. 1999. Dietary composition for grazing cattle of varying age and sex. Annu. Mtg. Soc. Range Manage. 52:25 (Abstract).

Livestock Performance on Improved Cool-Season Forages

M.R. Haferkamp, R.K. Heitschmidt, and E.E. Grings

Problem: Pastures seeded to cool-season grasses may be used to reduce grazing pressure on native ranges. They may also provide high quality forage for livestock in selected seasons. Many cultivars have been seeded, evaluated for forage production and quality, and persistence. As a result, some are recommended for use in the Northern Great Plains.

Palatability of some cultivars has been tested with livestock. However, few have been evaluated for livestock performance before being released. Grazing studies provide added information on livestock performance and stand persistence. This information cannot be obtained with small plot studies. For example, orchard grass cultivars were compared in haying and grazing systems. Their ranking in the two systems differed. Thus, grazing trials are needed before release of cultivars for commercial use. The goal of this project is to evaluate introduced and native cultivars and hybrids with emphasis on wheatgrasses.

Procedures: Twice replicated 7.4-acre pastures were seeded to Rosana western wheatgrass, Luna pubescent wheatgrass, and Hycrest crested wheatgrass in the fall of 1994. Forages are being evaluated for productivity, quality, stand survival, and animal performance.

Yearling cattle grazed the pastures from mid-April to mid-June 1997, 1998, and 1999. They were weighed and standing crop clipped monthly. Diet samples were obtained and analyzed for species composition and quality. Forage samples were dried, weighed, and analyzed for quality. Rainfall was monitored on site.

This work is in cooperation with the Forage & Range Research Laboratory in Logan, UT.

Findings: All stands of Hycrest crested, Luna pubescent, and Rosana western wheatgrasses established well in the twice replicated seeded 7.4-acre pastures, but by spring 1997 plants of Luna pubescent wheatgrass appeared to have died out on the ridges. Thus results again suggest the Pubescent-Intermediate complex is not adapted to dryland seedings in this area of the Northern Great Plains.

Each seeded pasture was grazed by 8 steers from 9 May to 12 June 1997. Steers were placed in each pasture when live grass standing crop averaged 814 lb/acre for Hycrest, 400 lb/acre for Luna, and 543 lb/acre for Rosana. Total grass standing crop averaged 475, 295, and 419 lb/acre when steers were removed. May standing crop for Hycrest was greater than that of Luna. Steers gained an average of 61 lbs/head and 2.53 lbs/head/day. No differences were detected in performance among grasses.

Eight steers were placed in each pasture on 24 April 1998, and re-mained until 15 June 1998. Live grass standing crop for Hycrest, Luna, and Rosana averaged 1,092, 607, and 670 lb/acre in April. Total grass standing crop averaged 2,271, 2,115, and 1,607 lb/acre in May; and 1,467, 922, and 794 lb/acre in June. April standing crop for Hycrest was greater than Luna or Rosana. Steer gains averaged [lbs/head (lbs/head/day)] 79 (3.0) for Hycrest, 73 (2.8) for Luna, and 64 (2.5) for Rosana from 24 April to 20 May. Gains on Hycrest were greater than for Rosana. Gains averaged 60 (2.3) from 20 May to 15 June and 132 (2.5) from 24 April to 15 June. Gains were similar among species from May to June and April to June.

Additional replicated pastures (8 acres each) were seeded in fall 1997 to 'Newhy' a wheatgrass hybrid, 'Boizoisky' Russian wildrye, 'Prairieland' Altai wildrye, and 'Alkar' tall wheatgrass. These will be used in future grazing studies emphasizing fall grazing. These pastures were mowed for weed management in 1998 and sprayed in spring 1999.

Future Directions: These studies were repeated in 1999. Additional evaluation will be initiated with newly established species in spring 2000.

Relevant Publications: Haferkamp, M.R., P.O. Currie, J.D. Volesky, B.W. Knapp, and K.R. Peterson. 1990. Effect of the 1988 drought on seeded rangelands in the Northern Great Plains, p.4-5. *In*: M.D. MacNeil, (ed.) Research for rangeland based beef production.

Haferkamp, M.R., D.C. Adams, M.M. Borman, P.O. Currie, B.W. Knapp, and K.R. Peterson. 1990. Response of the bluebunch wheatgrass-quackgrass hybrid to fertilization and defoliation, p. 9-11. *In*: M.D. MacNeil, (ed.) Research for rangeland based beef production.

Haferkamp, M.R., P.O. Currie, J.D. Volesky, and B.W. Knapp. 1992. Mortality of crested wheatgrass and Russian wildrye during drought. J. Range Manage. 45:355-357.

Haferkamp, M.R., D.C. Adams, E.E. Grings, and P.O. Currie. 1993. Herbage production and quality of RS2, a quackgrass (*Elytriga repens* [L.] Nevski.) x bluebunch wheatgrass (*Pseudo-roegneria spicata* [Pursh.] Love) hybrid, p. 897-898. *In*: M.J. Baker, J.R. Crush, and L.R. Humphreys (eds.) Proceedings XVII International Grassland Congress. Volume I. 8-21 February 1993. New Zealand and Queensland Australia.

Haferkamp, M.R., D.C. Adams, and P.O. Currie. 1993. Regrowth of the RS-hybrid with varying moisture conditions, p. 118-119. *In*: R.K. Heitschmidt, (ed.) Research and rangeland agriculture: Past, present, and future. Miles City, MT.

Booth, D.T. and M.R. Haferkamp. 1995. Morphology and seedling establishment, p. 230-290. *In*: D.J. Bedunah, and R.E. Sosebee (eds.) Wildland plants physiological ecology and developmental morphology. Society for Range Manage. Denver, CO.

Haferkamp, M.R., D.C. Adams, M.M. Borman, E.E. Grings, and P.O. Currie. 1995. Yield and quality of RS-2, a quack-grass x bluebunch wheatgrass hybrid. J. Range Manage. 48:362-369.

Haferkamp, M.R., H. Horton, and K. Asay. 1997. Reseeding the range. Montana Farmer Stockman, April. p. 10, 12-13.

Grazing and Drought Management

R.K. Heitschmidt, M.R. Haferkamp, and K.D. Klement

Problem: Drought is a common feature of rangeland environments. A basic question facing rangeland managers is how to manage grazing animals during drought. What are the immediate, short-, and long-term impacts of grazing during and after drought? Should livestock be removed from rangeland during drought and when should they be returned following drought? The goal of this research was to examine the impacts of grazing during and after drought relative to herbage production, tiller and root growth dynamics, seedbank composition, surface water runoff, and soil erosion.

Procedures: Experiment 1 was conducted from 1993 through 1996. An automated rainout shelter was constructed on a gently sloping clayey range site to control amount of precipitation received on treatment plots. The simulated drought was imposed from early June to mid-October 1994. During this time no rain was allowed to fall on the drought plots. Sheep were used to graze the plots in both early June and early July of 1994 and 1995. There were three grazing treatments, and two drought treatments. Grazing treatments were: 1) graze both the year of and the year after drought; 2) graze during the year of drought, rest the year after; and 3) rest both the year of and the year after drought. These same treatments were then repeated on non-drought plots.

Herbage production was estimated by frequent harvesting of standing crop. Tiller growth dynamics were monitored by repeated observations of marked tillers. Root growth dynamics were monitored using minirhizotron observation tubes. Germinable seed bank composition was determined by germinating seeds stored in ground litter and the top 1" of soil. Water budgeting variables were estimated by recording all precipitation events, collecting surface runoff, and monitoring changes in soil water.

Experiment 2 was conducted in a manner very similar to Experiment 1 except that the drought period was from early April to late June and the drought/grazing treatments were applied for two years (i.e., 1998-99) rather than just one.

Findings: All study results are for Experiment 1 only as Experiment 2 is on-going. Surprisingly, results showed that grazing treatment did not affect total forage production. Averaged across grazing and drought treatments, production was about 2350 lbs/ac in 1994 and 1975 lbs/ac in 1995 and 1996. However, grazing treatment did affect production of both the warm season perennial and annual grasses. Grazing during drought tended to decrease warm season grass production in the years after the drought regardless of whether plots were grazed or rested the year after the drought. The response was somewhat different for the annual grasses, such as Japanese brome and cheatgrass, in that grazing during drought only tended to reduce production of annual grasses if plots were also grazed the year following drought.

The tiller growth dynamics of blue grama and western wheatgrass were largely unaffected by the drought. Grazing, however, increased tillering rates of both species.

Total number of roots observed to a depth of 39" varied little among grazing and/or drought treatments. However, grazing tended to reduce the number of roots in the top 9" of the soil profile (A horizon) whereas drought reduced the number of roots deeper in the soil profile (i.e., 9 - 18", Bw horizon).

Several of our research projects at Fort Keogh have shown that the average number of native range germinable seeds per foot^2 is near 50. However, number of seeds can exceed 100 in certain instances. Studies have also shown that our seedbanks are dominated by annual grasses and forbs with few perennial grasses. This was also the case in this study. The 1994 drought treatment did reduce total number of germinable seeds/ft^2 from about 70 to 35 with most of the decrease being in annual grass seeds. However, the year after the drought (i.e., 1995), total number of germinable seeds was considerably greater in the 1994 drought than non-drought plots largely because of a dramatic increase in annual grass seeds.

The results from the water budgeting component of the study showed that amount of surface water runoff from these rangelands is very low during a growing season regardless of grazing treatment. It follows then that amount of soil erosion is very low as well.

The results also showed that most of the water received during a year is lost via evapotranspiration processes (>95%).

Future Direction: One of the short-comings of this experiment was that by the time the drought began to have impact on herbage production, most of the year's production was completed. Thus, the next series of experiments is looking at the impacts of grazing on these rangelands during and following spring time droughts (i.e., March - June). It is anticipated that a spring time drought will be much more devastating than the late spring to early fall drought (i.e., May - October) because a majority of the forage grown in the Northern Great Plains is grown during spring rather than summer.

Relevant Publications: Heitschmidt, et al. 1999. Drought and grazing: I. Effects on quantity of forage produced. J. Range Manage. (In press),

Emmerich & Heitschmidt. 2000. Drought and grazing: II. Effects on quantity and quality of water. J. Range Manage. (In review).

Hild, et al. 2000. Drought and grazing: III. Effects on root growth and seedbanks. J. Range Manage. (In review).

Eneboe. 1996. Tiller dynamics of blue grama and western wheatgrass subjected to drought and grazing. Master's Thesis, Dept of Anim. & Range Sci., Montana State University, Bozeman.

Management Strategies for Grazing Yearling Cattle

E.E. Grings, R.K. Heitschmidt, R.E. Short, B.S. Hould, and N.R. Bellows

Problem: Summer grazing of yearling cattle in addition to a cow-calf operation can aid in reducing economic risk. Use of yearling cattle to match the forage supply is a benefit in an environment with widely fluctuating rainfall patterns.

Rainfall in eastern Montana comes mainly during May and June. Low rainfall in late summer can result in lower forage quality and quantity leading to a reduced rate of gain by growing cattle. Strategies to overcome decreased gains in late summer may include removing cattle from rangeland before the decrease in forage quality and quantity or supplementation of limiting nutrients. Intensive early stocking may make better use of early season high quality forage for yearling cattle. It involves stocking pastures heavily early in the summer, when forage quality and quantity are high, and then removing the cattle when nutrition limits growth.

Previously, feeding extra protein to growing cattle during the summer increased weight gain and provided an economical means of improving production efficiency. The goal of this research was to test the value of providing extra protein compared with intensive early stocking.

Procedures: Each year, one hundred sixty-one British-type yearling steers were assigned to one of three treatments replicated in three pastures (89 to 195 acres). Major forage grasses in these pastures included western wheatgrass, needle-and-thread, threadleaf sedge, blue grama, buffalo grass, and Japanese brome.

Stocking rate was based upon Natural Resource Conservation Service guidelines for range sites in good condition. Treatments were 1) season-long stocking (SS), 2) season-long stocking, protein supplemented (SSP), and 3) intensive early stocking (IES). The SS and SSP steers were stocked at 12.4 acres per steer. The IES steers were stocked at 5 acres per steer. Protein supplement was group-fed to SSP steers after forage quality began to decline. Protein was fed as 4 pounds of a 27% crude protein soybean meal and barley-based pellet every third day. Dietary crude protein ranged from 12.4 to 16.8% in May and from 6.1 to 7.9% in late September. All steers were implanted before the study with a 200-day estradiol implant.

Findings : The IES steers tended to gain less weight than SS and SSP steers; however, production per acre was increased by 24 pounds. IES steers remained on pasture until mid-September of 1993 due to unusually high rainfall and forage quantity and quality that year. There was no effect of protein supplementation on weight gain of yearlings. Other studies indicate steers fed supplement decreased both forage intake and digestibility, thus accounting for the lack of response.

Table 1. Weight changes of yearling steers grazing Northern Great Plains rangeland in summer.

	Treatment		
	IES	SS	SSP
Initial weight, lbs	609	609	607
Weight after IES, lbs	860	882	880
Weight at end of grazing, lbs		944	946
ADG during IES period, lb/day	2.9	3.1	3.1
ADG after IES period, lb/day		1.8	1.8
Lbs gain/acre	53.0	28.5	29.6

Use of IES can improve production per acre in the Northern Great Plains. Late summer protein supplementation was not beneficial in this experiment. Results might differ on pastures having lower standing crop than that used for this study. This may explain the differing results between the present study and the one conducted in 1988-89.

Future Directions: Research on stocker cattle nutrition has stopped for the time being. Stocker cattle production strategies may be included in future research on rangeland-based beef production systems.

Relevant Publications: Currie, P.O., J.D. Volesky, D.C. Adams, and B.W., Knapp. 1989. Growth patterns of yearling steers determined from daily live weights. J. Range Manage. 42:393-396.

Grings, E.E., D.C. Adams, and R.E. Short. 1994. Protein supplementation of stocker cattle in the Northern Great Plains. J. Range Manage. 47:303-305.

Grings, E.E., R.K. Heitschmidt, R.E. Short, B.S. Hould and N.R. Bellows. 1996. Management strategies for grazing yearling cattle in the Northern Great Plains. Proc. 3rd Grazing Livestock Nutr. Conf., p. 145.

Grings, E.E., R.K. Heitschmidt, R.E. Short, B.S. Hould, and N.R. Bellows. 1996. Management strategies for grazing yearling cattle. Proc. Gov. Conf. on the State of the Cattle Industry. Billings, MT. p. 111-113.

Grings, E.E., R.E. Short, and R.K. Heitschmidt. 1997. Meeting nutrient needs of stocker cattle. Proc. 46th Montana Nutr. Conf. p. 53-56.

Grings, E.E. 1997. Summer stockers. Meeting the nutrient needs for growth when forage quality or quantity begin to decline. Western Beef Producer. June. p. 8-9.

Production Efficiency in Cattle of Two Growth Potentials on Rangeland During Spring-Summer Grazing

E.E. Grings, R.E. Short, M.D. MacNeil, M.R. Haferkamp, and D.C. Adams

Problem: Genetic selection and breed choice are two means used by the beef cattle industry to alter growth rate in cattle. The impact that increased growth rate may have on efficiency of production depends upon the growth stage of the animal and the environment where efficiency is measured. Cattle grazing on rangeland are subjected to a fluctuating environment with changes in nutrient quantity and quality throughout the year. This potentially limiting environment may affect the animal's ability to express genetic differences in growth potential and may, in turn, affect efficiency of production. The goal of this study was to evaluate the impact that cow size, steer sire growth potential, and steer age have on growth, intake and production efficiency of cattle grazing Northern Great Plains rangelands during the growing season.

Procedures: Data were collected on 24 cow-calf pairs during each of four summers (1989 to 1992) and on twelve 7-month-old and twelve yearling steers during three summers (1990 to 1992). Suckling calves and older steers were sired by either high- (Charolais with high EPD for yearling weight) or moderate-growth potential (Line 1 Hereford with average yearling weight ratios) bulls. Cow size was defined by scores developed from cow weights, condition scores, and hip heights.

Findings: Growth potential of calf sire did not influence efficiency of production to weaning, even though weaning weight was greater for the high growth potential calves in some years. High growth potential calves ate more forage to meet the nutritional demands for extra growth. Calf sire growth potential did not affect milk production or cow forage intake so that there were no extra nutritional demands placed on the cow rearing a high growth potential calf. Cow size did influence forage intake of cows, but not efficiency of production. Efficiency of production did increase with increasing milk production. Sire growth potential did not influence growth rate of older steers during the summer grazing season. Suckling calves were able to express genetic differences for growth during the early part of the summer grazing season while older steers were not.

Table 1. Organic matter (OM) intake for cows, calves, and steers throught the summer**.**

	June	July	Sept
	--OM intake, lb/day--		
Cow	19.2	22.0	21.4
Suckling calf,			
Forage	.9	1.8	5.1
milk	2.2	2.0	1.8
Fall-born steer	7.0	9.5	11.9
Yearling steer	10.4	13.0	14.3

Table 2. Efficiency of production (oz calf BW gain/lb forage organic matter intake by cow-calf pair) of weaned calf from rangeland with steer calves sired by bulls of two growth potentials.

	Sire Growth Potential	
Efficiency	High	Moderate
	1.5	1.4

Future Directions: This project was terminated after the collection of four years worth of data.

Relevant Publications: Grings, E.E., R.E. Short, M.D. MacNeil, M.R. Haferkamp, and D.C. Adams. 1996. Efficiency of production in cattle of two growth potentials on Northern Great Plains rangelands during spring-summer grazing. J. Anim. Sci. 74:2317-2326.

Weaning and Supplement Options for Cow-calf Pairs During Fall Grazing

R.E. Short, E.E. Grings, M.D. MacNeil, R.K. Heitschmidt, and M.R. Haferkamp

Problem: When to wean calves and whether to supplement cows during fall can be important decisions as they alter amount and efficiency of production. Cow size and growth potential of the calf also affect weaning weights and nutrient requirements. Decisions about these factors depend on the relative amounts and value of the inputs and outputs involved.

Management decisions not only affect production in the current year, they may also affect production in following years. These effects on later production are caused by changes in nutrient reserves of the cow and by her ability to adjust to nutrient restrictions. They are commonly measured by changes in body weight and condition score (BCS). Many studies have shown that decreased weight of the cow and BCS at calving may reduce the probability of breeding during the next breeding season.

The goals of this study were to determine effects of weaning date and supplemental feed on forage intake, cow and calf performance during the fall grazing period, subsequent production of the cow, and economic net return. Differences in cow size and genetic potential for growth of the calf were also evaluated.

Procedures: This research was conducted from late September to late December during 1989-1992. Each year, forty-eight crossbred cows with steer calves were assigned to one of eight treatments. Four experimental factors were evaluated: supplement or no supplement for the cows, weaning in September or December, calves sired by Hereford or Charolais bulls, and differences in cow size based on cow weight, height, and BCS.

Protein supplement was individually fed to one-half of the cows every third day (6.6 lb/feeding; 29.9% crude protein). Fort Keogh Line 1 Hereford bulls sired calves with moderate genetic potential for growth and fat deposition. Charolais bulls with high yearling weight indexes sired calves with high genetic potential for growth and low genetic potential for fat deposition. Two bulls of each genotype were used each year.

Data collected on cows included weight, BCS, hip height, milk production, forage intake, and diet quality. Data from calves included weight, forage and milk intake, and diet quality.

Rainfall and forage quality and production of the pastures were collected as a means of relating year-to-year differences to treatment responses.

Partial budgets were developed to evaluate these management practices. Steers that were weaned in December were charged grazing expense at a rate of .55 animal unit month (AUM). Steers that were weaned in September and grazed hay aftermath were charged grazing expense at a rate of .60 AUM. Supplement was priced at $240/ton. Calf prices were constant at $83.66/cwt.

Findings: When to wean calves and when and whether to supplement cows are major management decisions in a cow-calf enterprise. These decisions affect both economic and production efficiency. However, there is little data available to aid producers in the Northern Great Plains conditions in making those decisions.

Annual rainfall was quite variable during the study: 1988 was a very dry year, 1989 and 1990 were similar with adequate moisture early and dry falls, 1991 was a very wet year with September rainfall almost four times normal, and 1992 was consistently 10 to 20% above normal. These differences in rainfall were associated with marked differences in forage availability and diet quality.

If weaning was delayed from September until December, weaning weights were increased. More native range forage was also consumed. In years when forage quantity and(or) quality was limited, increased weaning weight came at the expense of decreased cow weight and BCS. These effects persisted through calving the next year. However, there were no detrimental carry-over effects on subsequent pregnancy rates and weaning weights. This lack of carry-over effects may be the result of using mature cows in this study and providing them adequate feed between weaning and breeding the next year.

Feeding protein supplement during the fall offset the negative effects of delayed weaning in years with limited forage resources. This practice consistently increased production efficiency and weaning weights by increasing milk production of the cow.

Differences in genetic potentials for growth and propensity to deposit fat affected both calf weaning weight and forage intake. As a result, there were no effects of genetic potential on efficiency.

Application of these results must take into account economic efficiency. Net returns from calves weaned in December were $15.84/head greater than from calves weaned in September. Feeding protein supplement also resulted in positive net return ($8.04/calf). As cost of inputs increase (supplements, grass, etc.) and(or) value of outputs decrease (calf prices at weaning), optimal management tactics change. For example, a $61.70/ton increase in price of supplement would negate the increased net return from feeding it to cows whose calves were weaned in December.

Future Directions: These data are being used in cooperative studies for modeling production systems.

Relevant Publications: Short, R.E., E.E. Grings, M.D. MacNeil, R.K. Heitschmidt, and D.C. Adams. 1996. Effects of time of weaning, supplement, and sire breed of calf during the fall grazing period on cow and calf performance. J. Anim. Sci. 74:1701-1710.

Effects of Growth Potential and Protein Supplementation on Steers Grazing Fall Pasture

E.E. Grings, R.E. Short, and D.C. Adams

Problem: Matching genetic potential of cattle with nutrient resources may benefit beef producers. At times, varying nutritional strategies may improve efficiency of production. Rate and efficiency of gain are important to profitable beef production. Increased weight gains may result from supplementing growing cattle grazing moderate quality forages. Effects of protein supplementation on forage intake and digestion depend on forage quality.

In fall, regrowth of irrigated hay fields may be of higher quality forage than native rangeland. Thus, regrowth may be a good choice of forage to more nearly match the nutrient requirements for growth of 6- to 9-month-old calves. However, protein needs of weaned calves depend on their growth rate. Pasture alone may not meet the protein needs of all types of calves. The goals of this study were to test the value of protein supplementation on intake and growth of calves of two growth potentials grazing fall pasture.

Procedures: The study was conducted from 1990 to 1992. Each year 23 or 24 steers grazed regrowth of a Russian wildrye - RS2 grass pasture from mid-October until mid-December. In mid-October, crude protein content of the forage consumed ranged from 10.6 to 13.2%. Quality decreased from October to December. Diet quality in mid-December ranged from 6 to 12.3% crude protein. Soybean meal was fed to one-half of the steers at 1 lb/head/day.

Findings: Weaned calves may gain 0.9 to 1.5 lb/day grazing regrowth on Russian wildrye - RS2 grass pastures in the fall. Feeding 1 lb/day of soybean meal may increase daily gains 0.4 lb.

Forage intake was an equal percentage of body weight for steers of high- or moderate-growth potential (1.95%). Thus, forage needs can be determined based on body weight. Both high- and moderate-growth potential benefitted equally from added soybean meal.

Future Directions: This project ended after three years. Studies on feeding added protein to improve production from rangelands continue.

Relevant Publications: Grings, E.E., R.E. Short, and D.C. Adams. 1997. Effects of growth potential and protein supplementation on steers grazing fall pasture in the Northern Great Plains. J. Prod. Agric. 10:241-245.

Lowering Beef Cattle Production Costs

R.N. Funston

"Low cost producers (in all segments of the production chain) will survive in this system of competitive markets. Others [high-cost producers] will eventually be unable to compete and will exit the business." This statement has never been more true than it is today. Many producers believe that they are at the lowest cost of production that they can be given their particular environment. The intent of this paper is to provide ideas for producers to possibly lower production costs even further.

$$\text{Breakeven Price} = \frac{(\text{annual 1cow costs} - \text{value of cull cows/bulls sold})}{\text{average weaning weight} \times \text{\% calf crop}}$$

The Profitability Formula

Management decisions should focus on decreasing costs while optimizing percent calf crop, weaning weight and market price. The most profitable combination of production and costs will vary from ranch to ranch and is largely dependent upon the unique set of resources each operation has. Table 1 demonstrates the effects of varying the annual cow costs and/or the weaning percentage on the unit cost of production in a herd with an average annual weaning weight of 550 pounds.

Table 1. Effect of cow costs and weaning percentage on unit cost of production with a 550 pound average actual weaning weight.

Weaning %	100	95	90	85	80
Weaning Wt.	550	523	495	468	440
Cow Cost	----Unit Cost of Production $/cwt----				
275	50	53	56	59	63
325	59	62	66	69	74
375	68	72	76	80	85
425	77	81	86	91	97

Goals for Long-Term Profitability

Following are proposed industry goals for factors in the profitability formula which have been proven to be attainable by many progressive cattle producers. These are critical factors for the success of any cattle operation. If you fall out of these ranges, it is important to take a closer look and identify problems within each component of the formula. Hopefully, this discussion will give some ideas on how to manage production costs without compromising reproduction or growth.

Cost of production - keeping break-even prices of calves near $.60/lb or lower.

Reproduction - optimum levels of % calf crop in the mid 80's to low 90% range - based on calves weaned per 100 cows exposed.

Growth - moderate average weaning weights in the 475-550 lb range for 7 month old calves.

How much can I afford to pay for increased production and/or reproduction?

Example: you determine your operation has annual cow costs of $275, 70% calf crop, and 550 lb weaning weight, based on goals for profitability, you determine your % calf crop is low. The question is: How much can I afford to pay in increased cow costs to raise % calf crop 15%? Disregarding cull animals, consider the following ratio.

$$\frac{275}{550\,x.70}=\frac{x}{550\,x.85}\rightarrow\frac{275}{385}=\frac{x}{467.5}\rightarrow x=\$333.93$$

This means that you could afford to increase cow costs $58.93 and maintain the same break-even of $.71, anything less than this and you would lower your break-even, the same scenario can be made for increasing weaning weight. The important consideration here is to make management decisions based on all factors affecting profitability. It is difficult to increase weaning weight or % calf crop without affecting cow costs, and decreasing cow costs often times adversely affects weaning weight and % calf crop. The intent of this paper is to give some management considerations that will decrease cow costs without adversely affecting production characteristics.

Cost of Production (Cow costs)
A recent IRM analysis indicated a 275% variation in cost of production between high and low cost producers which indicates opportunity for increasing profitability exists on most operations in the U.S. It has been estimated that less than 10% of today's beef producers know their cost of production, without knowing cost of production; it is difficult to reduce costs because we don't know where to begin to reduce costs.

Feed costs represent the single largest cost item for most cow/calf producers in all areas of the country. Between 40-70% of the total production costs come directly from feed and supplement costs. Other operating costs such as labor, interest, vet supplies, freight, fuel, and repairs also have a major impact but not to as great a degree as feed and supplement.

The competitiveness of the beef industry and particularly the cow/calf producer lies with the ability of cattle to convert forage into a product the consumer demands. Livestock management plans should be made to maximize forage utilization.

Minimize the use of harvested forages
1- Match the cow production cycle to the grazing season. Ideally the spring calving cow should graze green forage for about three weeks prior to the start of the breeding season. This coordinates the breeding season with peak forage production and best matches the time of highest requirements with the best grazing.

2- Use cool season forages to hasten and extend the grazing season. Cool season grasses have the potential to provide green forage up to 3 weeks earlier in the spring than native range. Higher quality fall forage can also be provided with cool season grasses.

3- Maximize the use of crop residues. Most areas of the U.S. have some form of crop residue which is typically the cheapest grazed forage available for use by beef cows.

4- Stockpiled forages managed for use during the fall and winter grazing will help reduce the amount of harvested forage required.

5- Early weaning will allow cows to increase body condition prior to the winter months and may allow a longer winter grazing period with reduced supplemental feed.

6- Proper range management can increase both carrying capacity and individual animal performance. Since forage is the base for any successful beef cattle operation, it is of vital importance to insure that this resource is sustainable and highly productive. Range management practices will vary depending on area and public land use. Some considerations include: rotational grazing, noxious weed control, water development, riparian area management, improved pastures, and sagebrush control.

Supplementation

An extended grazing season will likely involve grazing of poor quality mature forages which will be deficient in nutrients that will have to be supplemented if cow performance is to be maintained.

1 - Type

Protein vs Energy

This is really a misnomer, because high quality protein supplements contain similar energy as cereal grains. Soybean meal and corn have similar energy levels but will have different effects on digestibility and intake of poor quality forage. In general, protein is the first limiting nutrient in poor quality forage. Supplementation with an all natural protein supplement has been shown to increase digestibility and intake of poor quality forage and prevent loss of body condition during the winter grazing period. Supplementation to supply about 1/2 a pound of supplemented protein per head per day has been shown to be effective provided adequate forage is available for grazing. All natural protein supplementation has also been shown to be effective when fed on alternating or even every four days, provided animals receive an equivalent of 1/2 a pound of supplemental crude protein daily. All feedstuffs contain protein but all feedstuffs do not have the same effect on supplementing poor quality forage. Some examples of supplements which have a positive effect on digestibility and intake of poor quality forages include: alfalfa hay, high protein meals, high (20+ %)protein cake, wheat middlings, and corn gluten meal.

Mineral Supplementation

In general, when forages are deficient in protein, phosphorus is also deficient. Rations should be balanced for the macro and micro minerals. Minerals of primary concern include: calcium, phosphorus, magnesium, copper, zinc and selenium. There is extreme variation in micro mineral content of forages based on region. Phosphorus is generally the most expensive of the macro minerals to supplement.

Strategic supplementation 30-45 days pre-calving through the breeding season has been shown to be effective due to the ability of the animal to store minerals in the bones and liver. Strategic supple-mentation can reduce mineral costs considerably. Free choice iodized salt must be provided to animals at all times.

2- Cost

Price supplements on a cost per pound of nutrient basis. If protein is determined to be the first limiting nutrient, value supplements based on a cost per pound of crude protein basis.

Alfalfa hay valued at $80/ton with an 18% crude protein content would cost $.22/# of crude protein. (80/2000 = .04; .04/.18 = $.22/# CP). A 32% all natural cake valued at $200/ton would cost $.31/# CP. (200/2000 = .1; .1/.32 = $.31)

Genetic Management

Match cow type to forage base. High growth and milk production translate into increased nutrient requirements for the cow. Increased milk production and cow size increase both energy (TDN) and crude protein requirements (Table 2). A 1 pound increase in TDN would equal 2 pounds of average quality (50% TDN) forage and a 1 pound increase in crude protein would equal more than 4 pounds of 12% crude protein forage. Excess milk production and cow size can significantly limit the carrying capacity of any ranch operation.

Use crossbred cows to increase profits. It was determined from research at the Northern Agriculture Research Center near Havre, MT that crossbred cows have a substantial economic advantage over straight bred animals, primarily through increased longevity and calf weaning weight per cow exposed which takes into account calf weight as well as cow reproductive performance (Table 3).

Table 2. Relationship between cow size, milk production and nutrient requirements.

Cow Weight (lb)	Milk/day (lb)	TDN (lb/day)	Crude Protein (lb/day)
1000	10	11.5	2.0
	20	13.8	2.5
1200	10	12.8	2.1
	20	15.2	2.7
1400	10	14.0	2.3
	20	16.5	2.9
1600	10	15.1	2.4
	20	17.7	3.0

Source: Nutrient requirements of beef cattle; National Academy Press

Table 3. Advantage of crossbred cows (maternal heterosis) for economic traits

Trait	Maternal heterosis
Longevity	1.2 years (44%)
Calf weight weaned per cow exposed	74 lb (25%)
Net profit per cow exposed	$70

Source: Montana State University

It is important to remember that these animals have to be of the appropriate biological type to fit the environment they will be in. Research at Fort Keogh has demonstrated that both large body size and high milk production decreases longevity of crossbred females in that environment (Table 4).

Selection for economically important traits: What traits to select for and how much emphasis should be put on each is a common question in the beef industry today especially with the movement towards consideration for end product and value based marketing. This is not an easy question to answer due to the large number of traits that are of importance in beef production. The importance of traits varies depending on environment, management, economic conditions, and segment of the beef industry. Many **genetic antagonisms** exist in beef production today, among the most important include:

1. Milk production and growth rate vs fertility

2. Growth rate vs. calving ease

3. Lean yield vs. carcass quality

4. Milk production and growth rate vs maintenance requirements

These traits vary in rank of economic performance among segments of the beef industry; however, the final product must be considered in each segment if the beef industry is to overcome loss of market share it is experiencing today. Obviously compromises will have to be made and single trait selection will have to be replaced with a balanced trait approach.

There is a lot of talk in the industry about carcass traits; it is important to realize that unfavorable relationships exist between increased red meat yield and age at puberty, services per conception, and mature size. It is important to first match cow type to production environment and feed resources to reduce extremes that may compromise reproductive success and then consider other economically important traits.

Table 4. Longevity of crossbred dams varying in size and milk production

Biological Type of F1 Dams		
Size of Sire Breed	Milk Production	% in Herd after 6 Years
Medium	Medium	64
Medium	Higher	55
Large	Medium	41
Large	Higher	38

Source: Fort Keogh LARRS

Two strategies have been recommended to overcome or at least limit genetic antagonisms:

1. Find a happy medium by choosing appropriate breeds, breed combinations, and individuals within breeds. Some breeds or breed combinations are better with respect to a particular antagonism. For example, some breeds are sufficiently fertile that they can tolerate more milk and size before fertility becomes limited. Some breeds and breed combinations represent better compromises. British x continental crosses, for example, generally do better at producing carcasses with both quality and cutability.

2. Use terminal sires and heifer bulls. With terminal sires, we can have fast growing, efficient calves and still have a maternal cow herd that is fertile and easy to maintain. Carcass yield and quality can be excellent in this system as well. By using heifer bulls, calving difficulty can be reduced in first-calf heifers. Older cows can be bred to terminal high-growth sires.

Bull costs and bull:cow ratio can significantly impact cow costs (Table 5). A high priced bull may not always increase the value of offspring; make sure you have a marketing system to recapture the extra expense of higher priced genetics. Many production systems have been shown to successfully run one bull with 35-40 cows. Bulls must be in good body condition, checked for breeding soundness prior to breeding, and be in moderate sized pastures without extreme elevation changes for this to be successful. Increasing bull to cow ratios also requires closer observation of bulls during the breeding season.

Table 5. Bull costs per cow based on varying purchase prices and bull-to-cow ratios.

Bull Purchase Price	Total Bull Cost (4 yrs)[a]	Bull-to-Cow Ratio[b] 1:20	1:30	1:40
		----Bull Cost Per Cow----		
1000	1590	22.08	14.72	11.04
2000	3130	43.47	29.98	21.74
3000	4670	65.86	43.24	32.43
4000	6210	86.25	57.50	43.12

[a] Assumes $750 salvage value, $200/yr bull cost, 10% risk, 11% interest
[b] Assumes bull is used for 4 years; 90% conception rate each year.
Source: Colorado State University

Forage testing is one of the most cost effective technologies available to producers. Forage analysis will provide you with information to plan your winter feeding program to match the highest quality forages with the highest animal nutrient requirements. Often times forage is of higher quality than cow requirements. Overfeeding nutrients can be costly to a livestock operation and it may be profitable to sell higher quality products and replace with cheaper products or use higher nutrient forages as supplements for poorer quality forages.

Sort cattle based on body condition score and age, this is critical for re-breeding performance of the first calf heifer. Nutrient requirements for this class of animal are much higher than for mature cows. If there are extremes in body condition in mature animals it may also be profitable to sort and feed according to body condition. It is generally unprofitable to develop rations for the herd average especially if there is extreme variation in age and body condition.

Minimize the number of replacement heifers. High heifer replacement rates can greatly increase the cost of production, taking away resources available for producing cows. As mentioned previously, crossbred females have greater longevity than straight bred animals. Proper supplementation and body condition score management will also reduce the number of open cows each year. Consideration must also be given to raising vs purchasing replacement heifers.

Pregnancy check and cull open cows early may be a profitable alternative to traditionally selling in the fall when cull cow prices are at season lows, especially in times of limited forage availability. However, producers may want to consider keeping young open cows rather than raising replacement heifers. Open cows require less maintenance feed and generally have greater calving ease. This decision will depend on why the animal was open, her genetic merit, and the value of resources that particular year.

Develop a sound herd health program. It is not recommended to cut corners when it comes to herd health. Low-cost producers try to shift their herd health expenditures to preventive medicine rather than treatment. Most cost effective herd health programs focus on preventing: reproductive diseases in breeding stock, calf scours and respiratory disease in calves. Work with your veterinarian to establish management procedures that reduce herd health risks and develop a cost effective herd health plan.

Reduce labor costs through reducing use of harvested feeds, improving grazing management, purchasing replacements and buying hay may all be considerations which will decrease labor requirement.

Market don't just sell. Your cattle will be treated like a commodity until you differentiate them into a product. Provide the potential buyer with as much information as possible so that you receive the true value of your cattle:

- Use good management practices; dehorning, limited breeding season, castration.
- Keep records; genetic composition, implants and vaccinations, feedlot, and carcass data.
- Consider backgrounding.
- Comply with beef quality assurance guidelines and become BQA certified.
- Market through an alliance that rewards your type of cattle.

C. Enhancing Female Fertility

Fertility in beef cattle is regulated by many hormones that control reproduction and metabolism. Understanding the relationships among hormones, metabolism, and management factors, allows for control of the animal's system to enhance fertility. Measurement of hormones during studies allows scientists to evaluate the effects of various treatments on the body's regulatory mechanisms. Some studies involve the administration of hormones to enhance fertility or to control the timing of fertile periods.

Age at first calving affects lifetime production of beef cows. Pregnancy rates are greater when heifers are bred at third rather than the first estrus after puberty. Therefore, cycling before that breeding season begins may increase a heifer's lifetime production. Several factors affect heifer development, including nutrition. A variety of nutrients are involved in proper growth and sexual maturation. In addition, exogenous hormones may be used to hasten the onset of puberty. Therefore, studies dealing with nutritional management and the use of hormones are conducted to aid in the production of replacement heifers.

Pregnancy rate and conception date are important to the economic and biological efficiencies of beef production. Higher pregnancy rates and earlier conception result in more pounds of calf weaned per cow exposed. If heifers and cows are not cycling at the beginning of the breeding season, then they will conceive later (resulting in younger, lighter calves at weaning), or will not become pregnant at all. As with the onset of puberty, the onset on cycling after calving is affected by nutritional status and can be manipulated with hormonal therapy.

Researchers servicing the livestock industry strive to improve technologies for improving reproductive efficiency. These management strategies require testing under a variety of environmental and production conditions. This ensures the value of the tactic to a wide range of producers. Although some technologies are currently available to the producer, improved understanding of the biological system allows continued development of more efficient and cost-effective techniques to enhance fertility.

Time of Breeding of Replacement Heifers

R.B. Staigmiller, R.A. Bellows, and R.E. Short

Problem: Heifers that breed early in their first breeding season and that calve early in the first calving season not only wean heavier calves, but are destined to be good lifetime producers. The question is how to assure that heifers conceive early in their first breeding season. The goal of this research was to determine conception differences in heifers bred at their first (puberal) estrus or at their third estrus and to determine factors affecting any differences.

Procedures: One hundred fifty-six heifers were fed to gain 1.3 pounds daily from birth to puberty and were checked for signs of estrus. At estrus, heifers were assigned to be bred at either their puberal or third estrus. Ovulation was confirmed with ultrasound examination of the ovaries and by blood progesterone levels. A second study was conducted involving 70 heifers fed to gain either 1.3 or 2.2 pounds daily from weaning to puberty. Ovulation was also confirmed by ultrasound examination of the ovaries and by blood progesterone concentrations. At puberty the heifers were assigned to receive a frozen-thawed embryo from mature cows by nonsurgical transfer at either the puberal (first) or third estrus. Pregnancy for all heifers on both studies was determined by ultrasound examination of the reproductive tract at 26-33 days post breeding or at slaughter on days 19-23 post breeding.

Findings: Pregnancy rate of heifers bred at the puberal estrus averaged 57% compared to 78% for heifers bred at the third estrus. Pregnancy rate in heifers receiving a transferred embryo at the puberal estrus was 13% compared to 53% when the embryo was transferred at the third estrus. These findings show that pregnancy rate at third estrus is higher than at the puberal estrus. The reason is apparently due to a maturation of the uterine pregnancy maintenance mechanisms that occurs with additional cyclic activity. Practically, this work means that heifers should be developed so they are cycling before the breeding season begins so the heifer will not be bred at the puberal estrus.

Future Direction: These findings are considered definitive. The resources have been directed into research to determine relationships of body composition and attainment of puberty.

Relevant Publications: Byerley, D.J., R.B. Staigmiller, J.G. Berardinelli, and R.E. Short. 1987. Pregnancy rates of beef heifers bred either on puberal or third estrus. J. Anim. Sci. 65:645-650.

Staigmiller, R.B., R.A. Bellows, R.E. Short, M.D. MacNeil, J.B. Hall, D.A. Phelps, and S.E. Bartlett. 1993. Conception rates in beef heifers following embryo transfer at the puberal or third estrus. Theriogenology 39:315(Abstr.).

Effects of Diet, Trace Mineral Supplement, and Progestin Implant on Age at Puberty in Beef Heifers

E.E. Grings, J.B. Hall, R.A. Bellows, R.E. Short, S.E. Bellows, and R.B. Staigmiller

Problem: Exogenous hormones can be used to hasten the onset of puberty in beef heifers. However, response to exogenous progestin can be modified by the nutritional status of the animal when the hormone is given. Some information is available on the role of energy and protein in heifer development, but information on trace mineral needs is lacking, along with information on the interactions of mineral supplementation and feed source. Trace mineral supplements are advised for breeding cattle due to impaired fertility in subclinically deficient cattle. However, there are few controlled experiments in which marginal trace element deficiencies affected reproduction. The goal of this study was to examine effects of diet, trace mineral supplementation, and use of progestin implants on age of puberty in beef heifers.

Procedures: One hundred eighty heifer calves were assigned to treatments at weaning. There were four dietary regimens: corn silage vs pasture + oatlage with and without trace mineral supplement. One-half the heifers were given a progestin implant to induce puberty. Heifers assigned to pasture + oatlage grazed grass-legume pastures from October 14 until December 14. Then they were pen-fed an oatlage-based diet through May. Heifers on the corn-silage based diet were pen-fed throughout the study. Trace minerals were fed free-choice to heifers on pasture and top-dressed on feed in the pens. Progestin implants were placed in one-half of the heifers on April 11 for 10 days.

Table 1. Composition (DM basis) of diets and mineral supplements fed to heifers.

	Silage type		Mineral
Item	Corn	Oat	mix
Chemical Composition			
12-16-93 to 3-3-94			
CP, %	10.8	10.5	
Cu, ppm	5	3.0	600
Mn, ppm	40	48	1400
Zn, ppm	21	19	2000
Mo, ppm	.7	1.5	
S, %	.15	.18	
Rate of feeding - ounces per head per day			
12-16 to 3-3			2
3-3 to 5-27			3

During the breeding season, all heifers received a salt mix containing trace minerals. They were synchronized by feeding melengesterol acetate for twelve days. The heifers were then bred by AI after each observed estrus.

Findings: Of the implanted heifers, 88% reached puberty by the end of the study compared with 70% of non-implanted heifers. However, 84% of implanted heifers were pregnant in the fall compared with 92% of non-implanted heifers. Thus, progestin implants aid heifers in reaching puberty and may decrease age at first breeding. However, use of progestin implants to induce puberty may not be advisable if a similar treatment will be used later to synchronize breeding.

Heifers grazing fall regrowth of irrigated pastures reached puberty at similar ages to pen-fed heifers. Fall pregnancy rates of heifers managed under these dietary regimens were similar.

Providing trace mineral supplement before breeding decreased first service conception rates but not total AI pregnancy rates. However, plasma copper levels were quite low in one group of heifers that were not given the mineral supplement. Providing trace mineral salt mix for one month before and during the breeding season was adequate for reproductive performance.

Future Directions: A second study has been conducted with yearling heifers to further evaluate trace mineral supplement effects on growth and reproduction. Data from this second study are being analyzed.

Relevant Publications: None to date (July 1997).

Treatment of Prepuberal Heifers with Melatonin

R.A. Bellows and J.B. Hall

Problem: Successful and predictable induction of puberty in heifers would be a major economic advantage to producers. Altering light intensity and sequences has been shown to hasten or delay puberty. It has been suggested that these effects might be mediated through effects of the hormone melatonin. Melatonin is produced by the pineal gland in the brain. Its concentration can be altered by exposure of the animal to various light or darkness schemes. The goal of this study was to determine if melatonin and season of treatment would affect attainment of puberty.

Procedures: Twenty-two spring born heifers were assigned to receive saline injections (control) or be treated with slow-release melatonin implants. Melatonin was given on September 24, which was the approximate date of the fall equinox. This treatment was designed to plunge the animals into an artificial short day length.

Twenty-four heifers born in September were used in a second study. Twelve heifers received saline injections and twelve received the slow release melatonin implant on March 12. This was the approximate date of the spring equinox. This treatment was designed to plunge the animals into an artificial short day length.

Findings: When spring-born heifers were treated with melatonin in September, puberty was delayed. When fall-born heifers were treated in March, puberty was hastened. Blood melatonin analyses of samples from both control and treated heifers showed detectable melatonin concentrations. Concentrations found in the treated heifers suggested the melatonin dosage may have been too high. What effect this might have had on the results is unknown. These results are preliminary, but suggest that melatonin may be a factor in determining eventual age at puberty.

Future Direction: This work appears promising. It has been temporarily suspended due to lack of funds and labor.

Relevant Publications: Bellows, R.A. and J.B. Hall. 1996. Physiology and management of the replacement heifer. p. 217-234. In: L.M. Rode (ed.) Animal Science Research and Development, Meeting Future Challenges. Proc. 1996 Canadian Soc. Anim. Sci. Annual Meeting. Lethbridge, Alberta, Canada. July 7-11.

Effects of Dietary Fat and Sire Breed on Age at Puberty of Heifers

M.A. Lammoglia, R.A. Bellows, E.E. Grings, and R.E. Short

Problem: Numerous studies have been conducted to determine effects of dietary energy and protein on age of puberty in heifers. However, only limited information is available on puberty in heifers fed supplemental dietary fat. The goal of this study was to evaluate the effects of dietary fat on age of puberty, backfat thickness, and serum hormone levels.

Procedures: Two hundred and forty-six prepuberal heifers sired by Hereford, Limousin, or Piedmontese bulls were used in this study. Diets with 1.9% and 4.4% dietary fat were formulated to have equal levels of energy and protein. Safflower seeds containing 37% oil with 80% linoleic acid were used as a source of fat. The heifers were fed these diets from 8.5 months of age until they reached puberty or the breeding season began. Ration formulation was adjusted (without changing fat content) to maintain a growth rate of 1.7 lb/day and to meet NRC requirements for protein and minerals.

A blood sample was collected from all heifers between day 7 and 10 after estrus and serum progesterone levels were determined. At this time the ovaries were imaged ultrasonically for the presence of a functional corpus luteum (CL). Heifers were considered to have reached puberty when they showed estrous behavior with a CL capable of producing progesterone.

Blood samples were collected from sixty heifers representing both dietary groups and the three sire breeds every 28 days. Serum cholesterol levels were determined and backfat thickness was measured every 56 days using ultrasound to evaluate effects of the fat supplement.

Five Hereford-sired heifers fed each diet were intensively bled every 28 days. Blood samples were collected every 15 minutes for 4 hours. Plasma growth hormone and insulin levels were determined to evaluate diet effects on possible mechanisms controlling responses.

Findings: Feeding 4.4% dietary fat to heifers increased backfat thickness, serum progesterone, and cholesterol levels. Added dietary fat had no effect on plasma growth hormone or insulin levels. In addition, 4.4% dietary fat induced earlier puberty in Piedmontese-sired heifers, but not in Hereford- or Limousin-sired heifers.

Future Directions: This work has been terminated and the resources redirected to other studies.

Relevant Publications: Lammoglia, M.A., R.B. Staigmiller, R.A. Bellows, E.E. Grings, J.W. Bergman, R.E. Short, M.D. MacNeil, S.E. Bellows, and B.L. Balsam. 1997. Effects of dietary fat and sire breed on weight gain and reproductive traits of beef heifers. J. Anim. Sci. Abstr. (In Press).

Relationships of Body Composition and Metabolic Status to Puberty in Heifers

J.B. Hall, R.B. Staigmiller, and R.A. Bellows

Problem: Developing replacement heifers is an important, but costly part of the beef cow-calf industry. Nutritional effects on heifer growth have been known for years, but the mechanisms involved are poorly understood at best. The goal of this study was to determine if reaching puberty depended on the heifer reaching a certain metabolic status or body composition.

Procedures: One hundred thirty-two heifers were fed to gain either 1.3 or 2.2 pounds daily from weaning to puberty or slaughter. Body composition was assessed during the study using ultrasound and body condition scores. At slaughter, physical and chemical composition of the empty body were determined in a sample of 32 heifers.

Findings: Carcass measurements were similar to observations of the live animals. Heifers fed to gain 2.2 lb/day had more carcass and non-carcass muscle and fat than heifer fed to gain 1.3 lb/day. Insulin and blood urea nitrogen levels were greater in the rapid gaining heifers. However, growth rate did not affect hormonal growth factors. No dramatic changes in body composition or metabolic signals were detected before puberty. Puberty did not occur at similar body composition or metabolic status in all heifers.

Future Direction: Results of this study are considered definitive. These resources have been redirected into other phases of puberty research.

Relevant Publications: Hall, J.B., R.B. Staigmiller, R.A. Bellows, R.E. Short, W.M. Moseley, and S.E. Bellows. 1995. Body composition and metabolic profiles associated with puberty in beef heifers. J. Anim. Sci. 73:3409-3420.

Initiation and Synchronization of Estrous Cycles in Peripuberal and Postpartum Cows

R.E. Short and M.A. Lammoglia

Problem: Use of AI in beef production is partially limited by labor and management problems. These limitations may be overcome by using treatments to synchronize estrus. A variety of products synchronize estrus either by causing regression of the corpus luteum or inhibit estrus until their withdrawal. These products can be used in a variety of ways and combinations with reasonable success. However, none of the products or their combinations have FDA clearance for inducing estrus in either prepuberal heifers or postpartum cows. The goal of this research[1] is to evaluate new treatments for inducing and synchronizing estrus in prepuberal and anestrous postpartum cows.

Procedures: Four locations (Montana, West Virginia, Ohio, and Nebraska) cooperatively conducted the first experiment using 362 cows that were 25 to 50 days after calving and that had not resumed cycling. The primary product tested was a vaginal pessary that contains progesterone (EAZI-BREED™ CIDR®). Cows were allotted to one of four treatments: 1) a blank CIDR for 7 days, 2)

Table 1. Effect of progesterone(P) and(or) estradiol benzoate (EB) on induction of estrus, ovulation, and a functional corpus luteum (CL). Data are percentage of cows or heifers in each response category

	Treatment			
Response	Control	P	P + EB	EB
Cows				
Remained anestrus	34	30	16	34
Normal CL induced	16	**55****	**71****	20
CL formed late	7	0	0	16
Short cycle CL	29	5	4	12
CL formed early	14	9	9	19
Heifers				
Remained anestrus	63	43	17	
Normal CL induced	12	**44****	**66****	
CL formed late	8	11	13	
Short cycle CL	5	0	2	
CL formed early	12	3	2	

** These percentages were significantly increased by treatment with P and further increased by the P + EB treatment.

[1] This project was partially funded by InterAg of Hamilton, New Zealand. They seek FDA clearance for a product to induce and(or) synchronize estrus in beef cows and heifers. Their support for this research is greatly appreciated.

a progesterone CIDR for 7 days, 3) a progesterone CIDR for 7 days and injection of estradiol benzoate 24 to 30 hours after CIDR removal, or 4) a blank CIDR for 7 days and injection of estradiol benzoate 24 to 30 hours after CIDR removal. Cows were checked for signs of estrus for 14 days after CIDR removal, and blood samples were taken on days 8 and 15 to determine if ovulation had occurred.

The second experiment was conducted with 317 prepuberal heifers at seven locations in Montana, Ohio, Nebraska, Oklahoma, and Kansas. The heifers were confirmed to be prepuberal. The treatments were the same as treatments 1 to 3 in Experiment 1. Estrous detection and blood sampling to document ovulation was as in Experiment 1.

Findings: The results of both experiments are presented in Table 1. Progesterone CIDRs, especially when combined with an injection of estradiol benzoate, dramatically increased the percentage of cows and heifers forming a normal CL. The associated estrus and ovulation were closely synchronized, especially with the addition of the estradiol benzoate.

Anestrus cows and heifers can be induced to form normal CL using a combination of a vaginal pessary containing progesterone and an estrogen injection. The estrus and ovulation following these treatments is closely synchronized which will aid in the optimum timing of inseminations.

Future Directions: These experiments are continuing.

Relevant publications: Fike, K.E., M.L. Day, E.K. Inskeep, J.E. Kinder, P.E. Lewis, R.E. Short, and H.D. Hafs. 1997. Estrus and luteal function in suckled beef cows that were anestrous when treated with an intravaginal device containing progesterone with or without a subsequent injection of estradiol benzoate. J. Anim. Sci. 75:2009-2015.

Rasby, R.J., M.L. Day, S.K. Johnson, J.E. Kinder, J.M. Lynch, R.E. Short, R.P. Wettemann, and H.D. Hafs. 1998. Luteal function and estrus in peripubertal beef heifers given an intravaginal progesterone releasing device with or without a subsequent injection of estradiol. Theriogenology (In press).

Profitability of Estrous Synchronization with Natural Service

T.W. Geary, R.N. Funston, E.E. Grings, R.A. Bellows, and R.E. Short

Problem: Failure to rebreed is the single greatest economic loss to cow-calf producers and is the primary reason for culling cows from the herd. Beef cows often require 50 – 90 days to recover following calving until they resume reproductive (estrous) cycles that allow them to conceive and become pregnant. Cows that do not initiate estrous cycles before the start of the breeding season have fewer opportunities to conceive. These cows continue to calve later and later each year decreasing the age and value of their offspring. The Select Synch estrous synchronization protocol initiates estrous cycles in the majority of cows that are at least 40 days since calving and can be used to increase the opportunities that cows have within a defined breeding season to conceive. Computer models have demonstrated that use of this program with natural service may yield a 70-fold increase in cow-calf profitability. The goal of this study was to evaluate the impact of the Select Synch protocol under various range conditions on productivity and economic return.

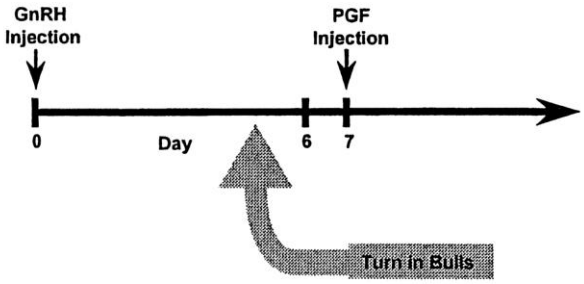


Figure 1. Select Synch protocol with natural service.

Procedures: Productivity and reproductive performance of beef cows receiving the Select Synch protocol are being evaluated in six herds located in Montana and Colorado. Herds ranged in size from 06 head to 1400 head and include breeding seasons that range in length from 32 to 75 days. One-half of the cows at each location receive the synchronization treatment and half of the cows will receive no treatment. The bull to cow ratio at each location is between 1:14 to 1:30. The Select Synch protocol includes administration of gonadotropin releasing hormone (GnRH) followed one week later by administration of prostaglandin (PGF; Figure 1). Two days prior to administration of prostaglandin, cows are exposed to bulls. Parameters measured include pregnancy rate, calving date, and subsequent rebreeding performance of cows, and calf age, weight, and value at weaning.

Preliminary Findings: Preliminary results from one of the beef herds from Colorado suggest a 20% higher pregnancy rate following a 50-day breeding season among cows that were synchronized using this protocol. In addition, among cows that were pregnant, the average calving date was 7 days earlier among synchronized cows. Calves were not individually identified at birth, which did not allow us to individually weigh calves at weaning. However, calves that are 7 days older at weaning would be expected to be 16 lb heavier at weaning and worth an additional $10. The higher pregnancy rate translates to fewer female calves being retained and developed for replacements in the breeding herd and represents tremendous savings to the producer. In addition, cows that have an additional 7 days to recover from calving to the start of breeding would be expected to have a slightly higher subsequent pregnancy rate and earlier average conception date.

Future Direction: Research may continue in this area to evaluate the appropriate bull to female ratio and optimal breeding pasture size. Further economic evaluations are also planned in this area.

Development of New Estrous and Ovulation Synchronization Protocols for Use in Beef Cows and Heifers

T.W. Geary and R.N. Funston

Problem: Artificial insemination (AI) with semen from genetically proven sires provides the quickest means for genetic improvement and selection of economically important traits. However, less than 6% of the beef cattle in the United States are artificially inseminated each year. The primary reason that so few cattle are artificially inseminated is due to the time and labor involved with detection of estrus and AI.

Artificial insemination is used in a higher percentage of beef heifers (~30%) than beef cows (~3%). The primary reasons for the greater use among heifers is due to the development of an estrous synchronization protocol that works well in heifers (but not cows) and because suckled cows represent extra work in the form of calf handling and care. Current estrous synchronization protocols minimize the amount of time spent observing cows and heifers to approximately 5 days. Development of inexpensive estrous synchronization protocols for both cows and heifers that allow timed insemination with minimal or no estrous detection would increase the use of AI by beef producers. The objectives of these studies are: 1) to decrease the cost of the CO-Synch estrous/ovulation synchronization protocol for use in beef cows (studies 1 and 2); 2) to evaluate timed insemination with the MGA/PGF protocol in beef heifers (study 3); and 3) to evaluate the addition of MGA to the Select Synch protocol for use in both beef heifers and cows (study 4).

Figure 1. Illustration of the CO-Synch protocol for synchronization of ovulation.

Procedures: *Study 1.* Approximately 400 beef cows from 2 locations have been divided to receive either the full dose or half dose of gonadotropin releasing hormone (GnRH) with the CO-Synch protocol (Figure1). Cows that exhibit estrus before the second GnRH injection and timed insemination will be inseminated approximately 12 hours later. Blood samples were collected from all cows at one location to evaluate the ability of the half dose protocol to induce estrous cycles as well as the full dose protocol. Pregnancy will be determined by ultrasound approximately 40 days following the timed insemination to evaluate effects of different dosages of GnRH.

Study 2. Seven hundred and sixty beef cows from a single location received the first two injections of the CO-Synch protocol (Figure 1). Cows that exhibit estrus within 72 hours following prostaglandin (PGF) injection will be artificially inseminated approximately 12 hours later. All cows that have not been detected in estrus by 72 hours following the PGF injection will be time inseminated with (2^{nd} GnRH) or without (no GnRH) a second injection of GnRH.

Pregnancy will be determined by ultrasound approximately 40 days following the timed insemination to evaluate the value of the second GnRH injection.

Study 3. Beef heifers (n = 604) from 3 locations received the MGA/PGF protocol for synchronization of estrus (Figure 2). Heifers were observed for signs of estrus for 5 days following the PGF injection. One-half of the heifers at each location were artificially inseminated approximately 12 hours after standing estrus (AIE) and the other half were inseminated at 72 hours following the PGF injection (TAI). Either even or odd numbered heifers received the AIE or TAI treatments at each location. Pregnancy rate will be determined by ultrasound approximately 40 days after the timed insemination to evaluate the need for heat detection.

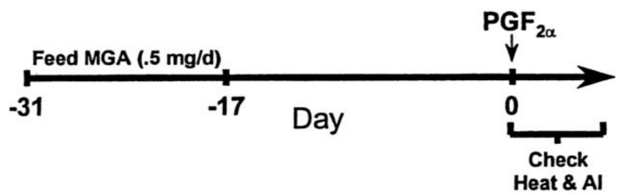


Figure 2. Illustration of the MGA/PGF protocol for synchronization of estrus.

Study 4. Beef heifers (n = 800) received either the MGA/PGF protocol (n = 400; Figure 2) or the MGA-Select Synch protocol (n = 400; Figure 3) for synchronization of estrus. Heifers that exhibited estrus were artificially inseminated approximately 12 hours later. Pregnancy rate will be determined by ultrasound approximately 40 days following synchronization to evaluate the success of the MGA-Select Synch protocol. If this protocol results in equal or higher pregnancy rates than the MGA/PGF protocol, we will evaluate the protocol in beef cows next year.

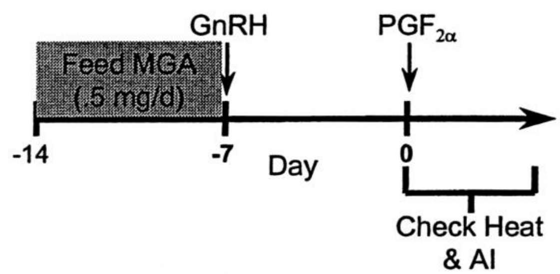


Figure 3. Illustration of the MGA-Select Synch protocol for synchronization of estrus.

Findings: We do not have any findings to report at this time.

Effects of Stair-Step Nutrition and Trace Mineral Supplementation on Attainment of Puberty in Beef Heifers of Three Sire Breeds

E.E. Grings, R.B. Staigmiller, R.E. Short, R.A. Bellows, and M.D. MacNeil

Problem: Lifetime production of the beef cow is affected by the age at puberty and age at first calving. While rate of gain is important in getting heifers to reach puberty at an early age, studies have reported that rapid growth during some phases of prepuberal development can result in decreased milk production. Researchers have successfully used stair-step nutritional management regimens to limit growth during critical periods of mammary development, followed by periods of rapid growth to allow heifers to reach puberty at an early age without harming later milk production.

Dietary copper (Cu) and zinc (Zn) are commonly found in cattle diets at less than recommended levels. However, effects of trace element supplementation on reproduction in controlled experiments have been varied. Diet and animal breed can both influence mineral utilization, and we wanted to evaluate mineral supplementation for heifers under different management strategies than that previously studied. The objective of this study was to determine the influence of nutritional management and trace mineral supplementation on attainment of puberty in beef heifers of three sire breeds and carryover effects on milk yield in the first lactation.

Procedures: Heifers were sired by Hereford (n = 15), Limousin (n = 18), or Piedmontese (n = 22) bulls bred to crossbred dams. Dams ranged in age from 2 to 11 years of age. Average birth date of heifers was April 10 and heifers were weaned at an average of 171 days of age. After weaning, 208 heifers were blocked by sire-breed and randomly assigned to either a control gain or stair-step gain dietary regimen plus a mineral supplement with or without Cu, Zn, and manganese (Mn) top-dressed onto the feed.

Table 1. Ingredient and chemical composition of diets fed to heifers before and during the treatment period for control gain (Control gain) and stair-step gain (Stair-step gain) treatments.

Composition	All heifers	Control gain	Stair-step gain High	Stair-step gain Low
Ingredient	--------------------	% DM	--------------------	
Corn silage	64.2	64.9	49.1	41.9
Barley	21.4	16.3	39.7	
Alfalfa hay	14.5	18.7	10.8	45.6
Barley straw				12.4
Sodium tripolyphosphate		.11		.07
Calcium carbonate			.34	
Chemical				
DM, %	43.9	42.12	51.2	46.9
CP, %	8.6	11.3	9.5	11.9
NDF, %	42.2	47.2	41.3	50.0
ADF, %	23.4	28.2	19.1	33.0
TDN, %	69.4	64.5	73.9	59.5
Ash, %	6.8	7.7	5.4	12.5
S, %	.15	.16	.17	.17
Cu, ppm	5.5	5.9	3.6	5.6
Zn, ppm	30.5	21.2	22.3	20.6
Mn, ppm	44.0	34.5	25.8	48.6
Mo, ppm	.5	.6	.9	1.4

Heifers were fed corn silage-based diets (Table 1) and were all fed the same diet for the first 2 months. Heifers on the stair-step gain regimen were then switched to a diet intended to supply energy to produce weight gains at 120% of the rate of the control gain diet. After 55 days, stair-step heifers were switched to a diet formulated to produce gains at 70% of the rate of the control gain diet for 84 days. They were switched back to the 120% diet for the last 30 days before breeding.

Beginning on day 29 after all heifers were placed on the common diet, trace mineral was top dressed onto the feed in the bunks at a rate of 3 ounces per heifer per day.

Heifers were determined to have reached puberty if, following an observed estrus, they had a corpus luteum and a serum progesterone concentration of greater than 1 ng/mL.

Table 2. Age at puberty, percentage pregnant, milk yield, and plasma minerals of heifers sired by Hereford (H), Limousin (L), or Piedmontese (P) bulls fed at a control gain (CG) or stair-step gain (SSG) plane of nutrition with or without supplementation of Cu, Zn, and Mn.

	Sire breed (SB)			Diet (D)		Mineral (TM)	
	H	L	P	CG	SS	-TM	+TM
Age at puberty, days	373	392	352	377	368	372	373
% pregnant	75.4	89.5	86.7	81.8	86.0	80.8	87.0
24-h milk yield, lbs							
6/18	12.8	13.2	11.5	12.1	12.8	12.8	12.3
8/6	9.3	10.4	8.6	9.0	9.9	9.7	9.3

Blood for mineral analysis was collected on the day before the start of mineral supplementation and after 172 days of supplementation.

After the study, heifers were allotted to pens based upon sire breeds. Crossbred bulls of the same sire breed were housed with the heifers for a 48-day breeding season. Pregnancy was confirmed by ultrasonography 63 days after the end of the breeding season.

Heifers were managed together until the last trimester of pregnancy when they were used in another research project. After calving, heifers were again managed as a single group. Only 142 heifers remained in the herd at the time of milk yield estimation. Milk yield was estimated by weigh-suckle-weigh technique twice, at approximately 70 and 120 days of lactation.

Findings: Trace mineral requirements for gestating cows are listed by the National Research Council to be 10 ppm Cu, 30 ppm Zn, and 40 ppm Mn. In addition, a Cu:Mo ratio of less than 4.5:1 is suggested as being preferable for improved Cu utilization. Dietary Cu was below 10 ppm in all diets and was only 3.6 ppm for the high Stair-step gain diet (Table 1). Dietary Zn was below recommended levels for all periods except the first 54 days when all heifers received the same diet. Dietary Mn was below recommended levels for the control gain and high stair-step gain diets. With these low dietary levels, some potential for animal response to supplementation exists.

Overall rate of gain did not differ between control or stair-step gain treatments. Rates of gain during specific periods were affected by diet as planned.

Sire breed affected weight gain throughout the study. Gains of Hereford- and Limousin-sired heifers did not differ and Piedmontese-sired heifers gained an average of .24 pounds per day slower than heifers of the other sire breeds.

The effect of mineral supplementation on weight gains was dependent upon the sire breed and nutritional management period but did not affect the overall weight gain or final weight of heifers. Age at puberty was affected by sire breed of heifer. Piedmontese heifers reached puberty at the earliest age followed by Hereford and then Limousin (Table 2).

There were no effects of sire breed or dietary treatment on pregnancy rates. Milk yield was determined at two times during the first lactation. There were no treatment effects on milk yield when measured at an average of 70 days of lactation (Table 2). However, at approximately 120 days of lactation, Piedmontese-sired heifers were producing less milk than Limousin- but not Hereford-sired heifers. Milk yield averaged across the two dates was greater for Limousin- than Piedmontese-sired heifers while that for Hereford-sired heifers did not differ from the other sire breeds. This had some relevance to calf preweaning average daily gain as calves produced through breeding Piedmontese-sired heifers to Piedmontese-sired bulls gained more slowly (1.47 pounds per day) than either Hereford- or Limousin-sired calves (1.58 and 1.65 pounds per day, respectively) which did not differ from one another.

Neither feeding regimen nor trace mineral supplementation during the yearling growth period had carry over effects on milk yield during first lactation.

Dam age did affect some weight variables and age at puberty. Increasing dam age resulted in linear increases in heifer weight both initially and at the end of the study. Age at puberty was older for heifers from younger dams.

The period between weaning and puberty is critical in the management of replacement heifers and rates of growth are influenced by breed and nutrition. In our study, sire breed of heifer had effects on growth, reproduction, milk yield, and plasma mineral concentrations, while there was little direct effect of either trace mineral supplementation or altering rates of gain from weaning through the beginning of the breeding season on reproductive performance and subsequent milk yield for beef heifers gaining over 1.32 pounds per day. This may allow for some flexibility in gain strategy and diet formulation and subsequent alterations in feed costs.

Future directions: We are conducting additional studies on the effects of rate of gain in heifers between weaning and first breeding. Evaluation is being based upon successful reproduction during a 32-day breeding season.

Relevant Publications: Grings, E.E., R.B Staigmiller, R.E. Bellows, and R.E. Short. 1999. Stair-step nutrition and trace mineral supplementation effects on puberty and reproduction in heifers. J. Anim. Sci. 77:810-815.

Rebreeding the First Calf Heifer

R.N. Funston and T.W. Geary

Rebreeding performance of the first calf heifer has major economic consequences. This classification of breeding animal is often the most challenging to manage for reproductive efficiency, primarily because this animal is not only subject to the stresses of calving and lactation for the first time but she is also still growing. Failure to rebreed after the first calf is one of the primary reasons for culling in a beef cattle operation in the Western United States. There is a considerable amount of money invested in this animal at this time and high replacement rates can greatly decrease the profitability of a beef cattle operation.

Breed heifers to calve earlier than the cow herd: Properly developed and managed beef heifers generally have a 20-30 day longer postpartum interval (interval from calving until fertile estrus) than older cows. The practice of breeding virgin heifers 20-30 days earlier than the cow herd will allow the heifer additional time to return to estrus and rebreed with the older cows the next year. It is important to manage these heifers separately for two reasons: 1) earlier calving will likely mean that pastures are not available as soon and additional nutrients will need to be supplied, and 2) nutrient requirements (% of ration) are higher for 1st calf heifers than for mature cows. Breeding heifers early may be of no benefit if they are not properly managed after calving.

Minimize the postpartum interval: The period from calving until the cow conceives is a very critical period in a cow's production cycle and minimizing this time period is critical for maximizing reproductive and economic efficiency of a beef cattle operation. Cows that cycle early in the breeding season have more opportunities to become pregnant during a limited breeding season. Keeping other factors constant such as genetics, age of dam and nutrition, cows conceiving early in the breeding season will have older calves that will have heavier weaning weights. The length of breeding season will influence uniformity of calves and their value at weaning. In order to have a successful short breeding season, it is vital that cattle cycle and conceive early in the breeding season.

Uterine involution is the time needed for repair of the reproductive tract so another pregnancy can be established. Uterine involution generally occurs within 30 days postpartum and does not generally limit cyclicity; however, factors such as malnutrition, disease and calving difficulty will delay normal involution.

Nutritional Management: Feeding a balanced ration to heifers in the last trimester of pregnancy through the breeding season is of critical importance. Nutritional demands increase greatly in late gestation and even more in early lactation. Reproduction has low priority among partitioning of nutrients and consequently, cows in thin body condition often don't rebreed. Plane of nutrition the last 50-60 days prior to calving has a profound effect on postpartum interval (Tables 1 and 2, Randel, 1990 and Bellows, 1995, respectively). The importance of pre- and postpartum protein and energy level on reproductive performance has been consistently demonstrated (Table 1). Positive energy balance postpartum is essential for prompt rebreeding of heifers that calve in thin condition (Table 3; Lalman et al., 1997). Recent research (Bellows et al., 1999) conducted at the Livestock and Range Research Laboratory at Miles City, MT, has demonstrated that fat from oil seed sources fed prepartum to heifers, increased conception rates and tended to increase calf weaning weights. Beef cattle do not have a fat requirement per se, but it is possible that providing this nutrient at times of high nutrient demand such as pre- and/or postpartum may increase reproductive efficiency.

Table 1. Effect of pre- or postpartum dietary energy or protein on pregnancy rates in cows and heifers.

	Adequate	Inadequate
Nutrient and time	Percent pregnant	
Energy level precalving[a]	73	60
Energy level postcalving[b]	92	66
Protein level precalving[c]	80	55
Protein level postcalving[d]	90	69

[abcd] Combined data from 2, 4, 9, and 10 studies, respectively.

Feeding a balanced ration the last trimester of pregnancy will decrease calving difficulty. Heifers fed diets deficient in energy or protein the last trimester not only experience more calving difficulty, but breed back later in the breeding season and have increased sickness, death and lower weaning weights in their calves (Table 2). Caution should be used with feeding excessive amounts of nutrients before or after calving. Not only is it costly, but animals with excess body condition (>7) have lower reproductive performance and more calving difficulty than animals in moderate body condition (5-6).

Table 2. Effects of gestation feed level on calving and subsequent reproduction.[a]

	Gestation diet of dam	
Item	Low	High[b]
Calf birth weight (lbs)	63	69
Dystocia (%)	35	28
Calf survival (%)		
At birth	93	91
Weaning	58	85
Scours (%)		
Incidence	52	33
Mortality	19	0
Dam traits		
Estrus (prior to breeding season (%))	48	69
Pregnancy (%)	65	75
Precalving pelvic area (cm^2)	256	271

[a]Averages from seven studies.
[b]Diet level fed from up to 150 days precalving; low and high, animals lost or gained weight precalving, respectively.

Overfeeding protein during the breeding season and early gestation, particularly if the rumen receives an inadequate supply of energy, may be associated with decreased fertility (Elrod and Butler, 1993). This decrease in fertility may result from decreased uterine pH during the luteal phase of the estrous cycle in cattle fed high levels of degradable protein. The combination of high levels of degradable protein and low energy concentrations in early-season grasses may contribute to lower fertility rates in females placed on such pastures near the time of breeding.

Table 3. Influence of postpartum diet on weight change, condition score (CS) change, and postpartum interval (PPI).

	Diet			
Item	Low	Main-tenance	Maint./ High	High
Weight, lb	835	822	826	821
Condition score	4.27	4.26	4.18	4.10
PPI, d	134	120	115	114
PPI wt. change, lb	12	40	70	77
PPI CS change	-.32	.37	1.24	1.50

Table 4. Relationship of body condition score (BCS) to beef cow performance and income.

BCS	Preg-nancy rate, %	Calving interval, d	Calf ADG, lb	Calf WW, lb	Calf price, $/100 lb	$/cow exposed
3	43	414	1.60	374	96	154
4	61	381	1.75	460	86	241
5	86	364	1.85	514	81	358
6	93	364	1.85	514	81	387

Body Condition Score: Body condition is correlated with several reproductive events such as postpartum interval, services per conception, calving interval, milk production, weaning weight, calving difficulty, and calf survival and can greatly affect net income on a cow/calf operation (Table 4; Kunkle et al., 1994). Body condition at calving is the single most important factor controlling when a beef heifer will cycle after calving. Heifers should have an optimum body condition of 5-6 at calving through breeding to assure optimal reproductive performance. Body condition score is generally a reflection of nutritional management; however, disease and parasitism can contribute to lower body condition scores even if "apparent" nutrient requirements are met.

Calving difficulty and time of intervention: Bellows (1990) indicated that cows that experience calving difficulty will take longer to cycle than cows not experiencing calving difficulty; therefore, it is important to minimize calving difficulty in your breeding herd. Time of intervention, when obstetrical assistance is needed, also affects cyclicity. Dams given early assistance had a reduction in postpartum interval, a higher percentage in heat by the beginning of the breeding season, a trend toward fewer services per conception, an increase in fall pregnancy rate, and heavier calves at weaning (Table 5). Therefore, early assistance, when needed, is important to assure heifers return to estrus as soon as possible.

Suckling stimulus from the calf has a negative effect on cyclic activity during the postpartum period; however, animals on a positive energy balance and in adequate body condition generally overcome this negative stimulus prior to the breeding season.

Calf removal, either temporary or permanent can increase the number of cows that return to estrus during the breeding season (Williams,1990). A common practice in some synchronization programs is 48 hr calf removal which has been shown to induce cyclicity in postpartum cows and first calf heifers. It is important to provide a clean, dry pen with grass hay and water and make sure that pairs "mother up" before going to pasture.

Table 5. Effect of time of calving assistance on dam breeding and calf performance.

	Time of assistance	
Item	Early	Late
Postpartum interval, (d)	49	51
In heat at beginning of breeding season (%)	91	82
Services/conception	1.15	1.24
Fall pregnancy (%)	92	78
Calf average daily gain (lb)	1.74	1.63
Calf weaning weight (lb)	422	387

Ionophores such as Bovatec® and Rumensin® have been shown to influence reproductive performance during the postpartum period. Cows and heifers fed an ionophore exhibit a shorter postpartum interval provided adequate energy is supplied in the ration (Table 6; Randel, 1990). This effect appears to be more evident in less intensely managed herds that generally have a moderate (60-85 days) or longer postpartum interval. Scientists have also demonstrated that heifers fed an ionophore reach puberty at an earlier age and a lighter weight.

Table 6. Effect of ionophore feeding on postpartum interval (PPI) in beef cows and heifers.

Study	Ionophore (PPI, d)	Control (PPI, d)	Difference (d)
1	30	42	12
2	59	69	10
3	67	72	5
4	65	86	21
5	92	138	46

Induction of estrus with hormones: Progestin containing products such as MGA (melengesterol acetate) or Syncro-Mate B can shorten the postpartum interval provided that nutrition and body condition are adequate. Gonadotropin releasing hormone (GnRH) is another hormone used in synchronization programs which will induce estrus in some heifers. None of these products are substitutes for good management, and heifers need to be at least 40 days postpartum before they will induce cyclicity.

Bull presence post-calving has been shown to cause heifers to cycle earlier. Bull exposure requires exposing heifers to surgically altered bulls that aren't capable of breeding from 30 days after calving to the start of breeding. Approximately one bull per twenty heifers is required and limited data suggests exposure to androgenized steers or cows will produce similar results.

Herd Health: A sound herd health program is an essential part of any reproductive management system. Cattle are susceptible to a variety of diseases which are detrimental to reproduction. All herd health programs should be implemented under the supervision of a qualified, licensed veterinarian. A relationship exists between poor nutrition and increased incidence of herd health problems. Several vitamins and minerals are necessary for immune system function and nutrient deficiencies in these areas can result in an increased susceptibility to disease.

Summary:

1. Breed heifers 20-30 days before the cow herd.

2. Make sure heifers are on a balanced ration the last trimester of pregnancy through the breeding season.

3. Heifers should be in optimum body condition (5-6) at calving and through the breeding season.

4. Provide calving assistance in a timely manner when needed.

5. Use an ionophore for increased feed efficiency, coccidiosis control, and the positive affect on reproductive performance.

6. Progestins, GnRH, 48-hour calf removal, and bull exposure are management tools that can induce cyclicity in some heifers.

7. A sound herd health program is essential for optimum reproductive efficiency.

There are several management practices that can assist in shortening the postpartum interval but none of these recommendations will take the place of good management. Body condition, level of nutrition, age of cows, milk production, weather, disease, parasites, and other factors will affect the ability to shorten the postpartum interval. The first place to address this problem is with proper nutrition prior to calving and through the breeding season and managing for optimum body condition.

References: Bellows, R.A., Simms, D.D., Grings, E.E., Phelps, D.A., Bellows, S.E., Bellows, N.R., Short, R.E., Funston, R.N., and Geary, T.W. 1999. Effects of feeding supplemental fat during gestation on reproduction in primiparous beef heifers. J. Anim. Sci. 77 (Suppl. 1): (Abstract) (In Press).

Bellows, R.A. 1995. Managing the first-calf heifer. In: Proc., International Beef Symposium. January 18-20. 1995. Great Falls, MT. p 74-85.

Elrod, C.C. and W.R. Butler. 1993. Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein. J. Anim. Sci. 71:694-701.

Kunkle, W.E., R.S. Sands, and D.O. Rae. 1994. Effect of body condition on productivity in beef cattle. M. Fields and R. Sands (Ed.) Factors Affecting Calf Crop. Pp 167-178. CRC Press.

Lalman, D.L., D.H. Keisler, J.E. Williams, E.J. Scholljegerdes, and D.M. Mallett. 1997. Influence of postpartum weight and body condition change on duration of anestrus by undernourished suckled beef heifers. J. Anim. Sci. 75:2003-2008.

Randel, R.D. 1990. Nutrition and post-partum rebreeding in cattle. J. Anim. Sci. 68:853-862.

Selk, G.E., R.P. Wettemann, K.S. Lusby, and R.J. Rasby. 1986. The importance of body condition at calving on reproduction in beef cows. OK Animal Sci. Res. Rept. OK State Univ. MP-118.

Williams, G.L. 1990. Suckling as a regulator of postpartum rebreeding in cattle: a review. 1990. J. Anim. Sci. 68:831-852.

D. Calving Difficulty and Calf Survival

Calving difficulty is an important cause of calf death at or shortly after birth. These losses have a marked negative impact on profit of ranching operations. Annual costs are estimated at more than $150 million nationwide and exceed $2 million in Montana. In addition to lost income from calves dying at birth, dystocia influences rebreeding performance of the dam and weight gain in calves surviving a difficult birth. Previous research has explained about 50% of the control of calving difficulty. Calf birth weight is the most important followed by sex of calf, and body weight and pelvic area of the dam. Nevertheless, about 50% of the variation in calving difficulty is due to hormone abnormalities and unknown factors.

About 10% of calves born do not survive to weaning. Many of these die due to cold stress at or near calving. Calves use several mechanisms to keep warm and the efficiency of these systems can vary. Understanding these mechanisms improves our ability to manipulate them and improve the calf's chance of survival.

Some calf losses are associated with disease and with the consumption of poisonous plants. Pine needle abortion is a source of significant calf losses in some areas. Consumption of pine needles by pregnant cows results in a premature birth and calf survival is limited. Preventing this problem can be approached by two methods: blocking the mechanism that causes the premature birth, or prevention of the consumption of pine needles. The search for a preventive or cure for pine needle abortion has provided some new insights into mechanisms controlling the birth process and dietary preference of the pregnant cow.

Joint Effects of Fetal and Maternal Genotypes on Calving Difficulty

R.A. Bellows, R.B. Staigmiller, and R.E. Short

Problem: Information is available regarding sire effects on calving difficulty, but relatively little is known about the effects of the dam. Differences in maternal uterine environment may affect birth weight and little is known about how the growth potential of the gestating calf interacts with the uterine environment. The goal of this research was to establish joint effects of fetal growth potential and maternal uterine environment on calving difficulty.

Procedures: Study 1: Ninety-three cross bred cows were superovulated and bred to either a Jersey or Charolais sire. The pregnant cows were slaughtered at either 95, 180, or 250 days of gestation. Detailed fetal weights and measurements were collected.

Study 2: Forty-six heifers sired by Brahman, Charolais, Jersey, Longhorn, or Shorthorn bulls were bred to one of two Angus sires. These Angus bulls were selected to produce either high or moderate fetal growth. Daily blood samples were obtained for four days before slaughter at 231 days of gestation. Fetal weights and detailed measurements were collected at slaughter. Blood samples were analyzed for estrogen, progesterone, and testosterone content.

Findings: Study 1: Fetal weights and measures of Jersey and Charolias-sired calves were similar at 95 days of gestation. However, male fetuses were larger than female fetuses at 95 days of gestation. Type of pregnancy (single vs multiple) had significant effects on placentome and membrane weight. At 180 and 250 days of gestation, type of pregnancy had greater effects on conceptus traits than did fetal sex. Growth of multiple fetuses sired by the Jersey sire was reduced and became more pronounced as gestation progressed. Relationships among fetal traits and dam carcass traits indicated fatter dams produced lighter fetuses. We conclude the genetic contribution for fetal growth has a positive influence on fetal growth and size throughout gestation. The importance of metabolite availability may change during gestation depending on fetal growth potential and whether the pregnancy is single or multiple. These fetus-dam relationships appear to involve systems controlling fetal growth that arise from the fetal growth potential interacting with effects that may be related to carcass traits of the dam.

Study 2: Fetuses from Charolais and Shorthorn dams were the heaviest as were fetuses from the high growth-rate sire. Placentome number was the lowest, but placentome weight the highest in Jersey dams. Fetus weight increase from the high growth sire was greatest in Jersey dams. Brahman dams reduced expression of the fetal growth potential. No breed of dam or sire effects were found on estrogen or progesterone concentrations. Testosterone concentrations were higher in dams with male fetuses and fetuses sired by the high growth sire. Thus, some maternal environments allow maximum expression of the fetal genetic growth potential. Whereas, other maternal environments suppress expression of fetal growth potential.

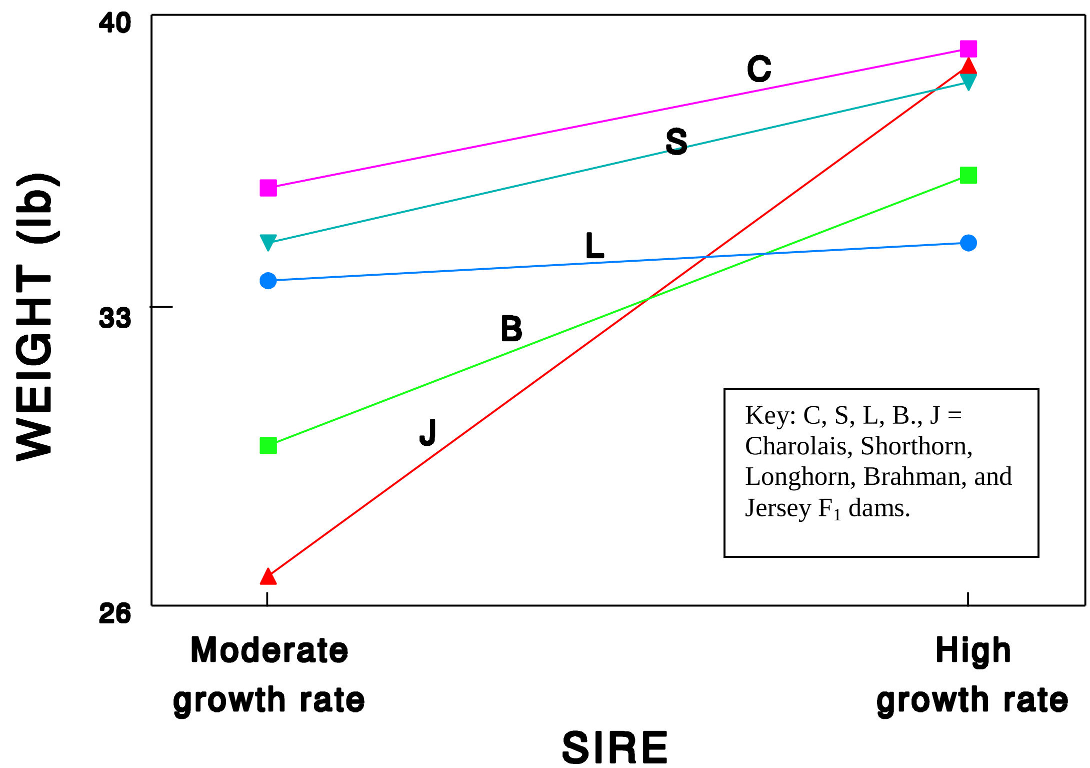


Figure 1. Fetal genotype by maternal uterine environment effects on eviscerated fetus weight at 231 days at gestation.

Dams gestating male fetuses were subject to prolonged testosterone influence which may affect subsequent dystocia, calf survival, and incidence of retained fetal membranes.

Future Direction: Work on defining hormonal involvement in calving difficulty continues. New studies will determine how these changes correlate with body temperature changes in the dam at calving.

Relevant Publications: Bellows, R.A., R.E. Short, G.P. Kitto, R.B. Staigmiller, and M.D. MacNeil. 1990. Influence of sire, sex of fetus and type of pregnancy on conceptus development. Theriogenology 34:941-954.

Bellows, R.A., R.B. Staigmiller, L.E. Orme, R.E. Short, and B.W. Knapp. 1993. Effects of sire and dam on late-pregnancy conceptus and hormone traits in beef cattle. J. Anim. Sci. 71:714-723.

Can Balancing Birth Weight and Growth Improve Calving Ease

M.D. MacNeil, W.M. Snelling, and J.J. Urick

Problem: Genetic selection to increase production tends to decrease net reproduction. Improving more than one unfavorably correlated traits at a time can be difficult. Reducing calf mortality by controlling birth weight while increasing later growth is an applied example of this problem.

Calves that are too heavy at birth are likely to be born with severe difficulty. However, birth weight is positively correlated with weights at later ages. Thus, selection for reduced birth weight may alter production efficiency by reducing growth from birth to market weight. The goal of this research was to study a genetic selection strategy with negative emphasis on birth weight and positive emphasis on later growth.

Procedures: In 1977, the Miles City Line 1 Hereford cow herd was randomly divided into two sublines. These sublines were maintained as separate breeding populations in this study.

Sires for one subline (YB) were selected for below average birth weight and high yearling weight. Sires for the second subline (YW) were selected for high yearling weight alone. Selection decisions were based on individual performance adjusted for age of dam effects. Performance of relatives was not considered in making selection decisions. Sires were used as yearlings and 2-year-old for either 1 or 2 years. In both sublines, the selection was restricted such that no parent left more than two sons as sires.

Heifers were selected on the criteria appropriate to their subline with the added requirement of being pregnant as yearlings. Selected females remained in the herd until they were open twice, became unsound, or reached 10 years of age. During the calving season, 2-year-old heifers were observed continuously. Heifers not giving birth within approximately one hour of their first being observed in labor were assisted in delivering the calf.

Findings: Both selection lines were 5.2 generations removed from the base population at the end of the experiment. Total selection applied to birth weight in the YB selection line, averaged over sex of progeny, was -12.8 lbs. In contrast, basing selection decisions on yearling weight alone in the YW line resulted in +36.3 lbs of selection applied to birth weight. Total selection applied to yearling weight was +706 lbs in the YW selection line versus +449 lbs in the YB selection line. These differences between YB and YW in selection applied are the basis for expecting growth to differ between lines.

In the YB line, direct breeding values for birth weight trended slightly negative. Whereas, in the YW line, they trended upward in response to selection for yearling weight. Maternal genetic effects on birth weight increased slowly and similarly across lines. Thus, selection for below average birth weight in addition to high yearling weight fully offset the increase in birth weight resulting from selection for increased yearling weight.

Direct genetic effects on 365-day weight increased more slowly in YB than in YW as would be expected from the difference in selection applied. Maternal genetic effects were similar and nearly constant in both YB and YW. The nearly 20 pound reduction in genetic response in 365-day weight of YB compared with YW is the cost of limiting genetic increase in birth weight.

Estimated direct and maternal heritabilities for calving ability were .31 and .04, respectively. Thus, it appeared the genetic control of calving ability was more nearly a trait of the calf than a trait of the dam.

The expected outcome of this study was a lower rate of assisted calving by 2-year-old heifers in the YB line relative to the YW line. Heifers in the YW subline did require more frequent assistance at calving relative to heifers in YB. However, all of the response in calving ease was observed in the first generation. No further improvement in calving ease was seen.

Selection of low birth weight sires with high genetic potential for subsequent growth appears to be a valid management strategy for controlling the incidence of calving difficulty in 2-year-old heifers. However, it is not a strategy that will necessarily result in genetically improved calving ability.

Future directions: Growth from one year of age to maturity will be analyzed to assess the impacts of these selection strategies on maturing rate and cow size. Crossbred calves sired by many of the bulls used in this study have been fed out and slaughtered with carcass data collected. These data too will yield information on the different strategies of sire selection and relationships of body composition with maturing rate and mature size.

Relevant Publications: MacNeil, M.D., J.J. Urick, and W.M. Snelling. 1997. Comparison of selection by independent culling levels for below average birth weight and high yearling weight with mass selection for high yearling weight in beef cattle. Journal of Animal Science. (In press).

Calving Difficulty in Brahman-Cross Heifers

R.A. Bellows, P.C. Genho, and S.A. Moore

Problem: Previous work has shown that high calf birth weights are the most important cause of calving difficulty. Small frame heifers with small pelvic areas have a greater probability of experiencing calving difficulty. There is recent interest in using pelvic measurements to predict potential for calving difficulty in heifers. Those heifers could then be culled before calving.

Brahman and Brahman-cross dams have the ability to control calf growth in the uterus during gestation resulting in lower birth weights and reduced calving difficulty. Also, cattle reared in sub-tropical environments typically have lower birth weights and less calving difficulty than those reared in temperate environments. The goal of this study was to establish relationships between body measurements of the heifer and calving difficulty when incidence of calving difficulty is expected to be low.

Procedures: This study was conducted in Florida with 666 Brahman-cross heifers. It took place on a ranch where calving difficulty has been much less frequent than in the Northern Great Plains. Data collected at the end of the breeding season included body weight, condition score, hip height, heart girth, plus pelvic height, width, and calculated pelvic area. These data were used in an attempt to predict calving difficulty.

Findings: Data obtained at the end of the breeding season were of little value in predicting calving difficulty. However, calf birth weight was a consistently important cause of calving difficulty in this environment where birth weights are low. Severity of calving difficulty was increased with very low birth weights,

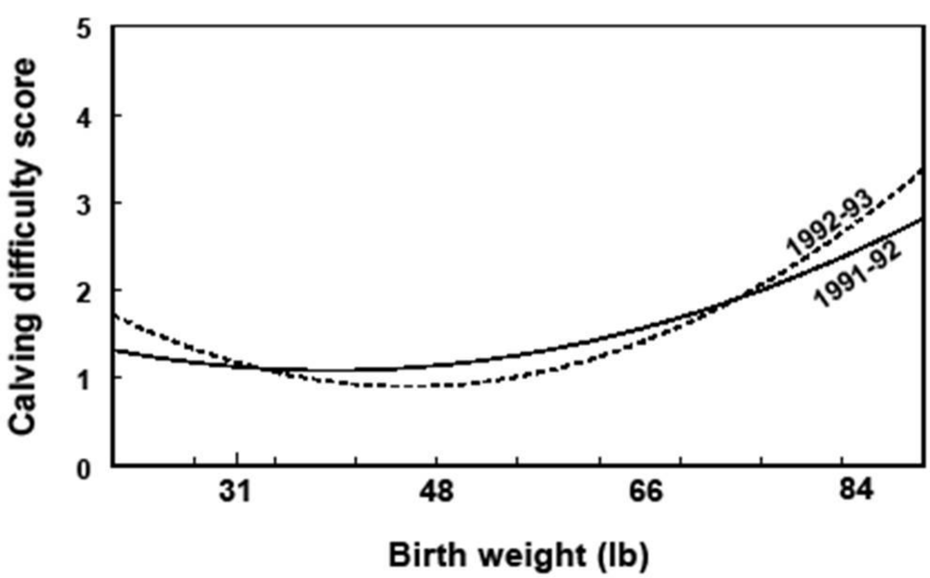


Figure 1. The relationship between calving difficulty score and birth weight of calves.

lowest with intermediate birth weights and highest with heaviest birth weights. Calving difficulty was least severe when birth weight was about 50 pounds.

These findings are consistent with work in temperate regions. Thus, birth weight is an important cause of calving difficulty regardless of geographical region.

Future Direction: These results are considered definitive. The resources used in this study are now being used in other research.

Relevant Publications: Bellows, R.A., P.C. Genho, S.A. Moore, and C.C. Chase, Jr. 1996. Factors affecting dystocia in Brahman-cross heifers in subtropical southeastern United States. J. Anim. Sci. 74:1451-1456.

Bellows, R.A. and M.A. Lammoglia. 1996. Management decisions to optimize reproduction and profit. Proc. Governors Conf. on the State of the Cattle Industry, Billings, MT. August. P. 95-99.

Effects of Gestation Exercise

R.A. Bellows, R.E. Short, and R.B. Staigmiller

Problem: It is common thinking among cattle producers that the pregnant dam must have exercise during gestation to maintain sufficient muscle tone and strength to expel the calf without problems during labor. The goals of this study were to determine if exercise of pregnant cows effected incidence or severity of calving difficulty or rebreeding of the cow after calving.

Procedures: The effect of exercise during gestation on dystocia was studied in 118 pregnant heifers and cows. Major differences in exercise were created between two groups of dams during the last 90 days before calving. Dams assigned to restricted exercise were held in feedlots. Those assigned to the high exercise group were held on a range pasture and fed one mile from the only water source. Thus, these cows walked 2 miles as they traveled from the feed ground to water and returned daily. They were weighed periodically during the study and were fed to make about the same gains during the 90 days before calving. All cows and heifers were calved in feedlots and were observed 24 hours daily.

Findings: Exercise during late gestation had no effect on calf birth weight, incidence, or severity of dystocia. However, feed required to maintain body weight gains increased more than 31%. Even with the increased feed, cows and heifers with limited exercise gained more during late gestation that those on range. Those females that were forced to exercise had a 15% higher pregnancy rate in the following 45-day breeding period than cows and heifers with restricted exercise. This increased pregnancy rate may result from a feed-endocrine rebound in cows and heifers forced to exercise. Since these cows and heifers received 31% more feed during gestation, gut size may have been greater allowing them to consume more forage during the breeding season and resulting in a positive effect on reproduction.

Future Direction: Results of this work were definitive. Resources used have been redirected.

Relevant Publications: Bellows, R.A., R.E. Short, and R.B. Staigmiller. 1994. Exercise and induced-parturition effects on dystocia and rebreeding in beef cattle. J. Animal Sci. 72:1667-1674.

Exercise Group	Relative feed Required (%)	Birth Weight (lb)	Calving Difficulty Incidence (%)	Calving Difficulty Score	Fall Pregnancy (%)
Restricted	100	73	27	1.5	76
Forced	131	71	22	1.4	91

Effects of Relaxin on Calving Difficulty

R.W. Caldwell and R.A. Bellows

Problem: Many hormone changes occur just before calving. These hormones act on the uterus, pelvic ligaments, and structure of the birth canal. Relaxin is a hormone that expands the birth canal and aids birth in other species. The goal of this study was to determine if treatment with relaxin would reduce incidence or severity of calving difficulty in beef heifers.

Procedures: Thirty-six cross bred heifers were assigned to receive no treatment or 3000 units of pig relaxin. Relaxin was injected at 4 or 7 days before the predicted day of calving.

Findings: Relaxin treatment had no effect on gestation length, calf birth weight, calf vigor, incidence or severity of calving difficulty, or incidence of retained placenta. Pelvic expansion during the 6 days prior to calving was greatest in dams gestating male calves.

Future Direction: Results of this study are definitive. Resources used have been redirected.

Relevant Publications: Caldwell, R.W., R.A. Bellows, J.A. Hall, and R.V. Anthony. 1990. Administration of porcine relaxin to beef heifer at four or seven days prepartum. J. Repro. Fert. 90:165-174.

Bellows, R.A. 1991. An overview of calving difficulty. Proc. International Beef Cattle Symp. Animal and Range Sci. Dept., Montana State University and Ag. Canada, Lethbridge, Alberta. January 15-17. Great Falls, MT. p. 114-123.

Bellows, R.A. 1992. Decreasing calf losses. IN: 12th Ann. Utah Beef Cattle Field Day. Brigham Young Univ., Provo, UT. p. 1-11.

Bellows, R.A. and R.E. Short. 1994. Reproductive losses in the beef industry. p. 109-133. IN: M.J. Fields and R.S. Sand (eds.) Factors Affecting Calf Crop. CRC Press, Boca Raton, FL.

Dietary Protein Effects on Calving Difficulty and Maternal Hormone Patterns

R.A. Bellows, R.B. Staigmiller, and R.E. Short

Problem: Earlier studies examining effects of dietary protein levels on birth weight and calving difficulty have produced conflicting results. The goal of this study was to resolve this conflict, because normal growth depends on adequate dietary protein.

Procedures: Fifty-nine crossbred heifers were fed either low (81% NRC) or high (141% NRC) crude protein in diets of equal energy content. Heifers were individually fed daily for 75 days before calving. Blood samples were taken and analyzed for hormone and metabolite concentrations to determine effects of diet and relate these to differences in calving difficulty.

Findings: Protein level of the diet had no effect on birth weight or calving difficulty. Thus, feeding low-protein rations in hopes of reducing calving difficulty seems ill-advised.

Heifers fed the low protein diet gained weight more slowly during late pregnancy than those fed the high protein diet. Blood urea nitrogen and glucose were lower and progesterone levels higher in heifers fed the low protein diet.

Estrogen levels normally rise before calving. However, this rise was quite different in heifers having difficulty calving. Blood urea nitrogen, glucose, and progesterone concentrations also differed between heifers having difficulty

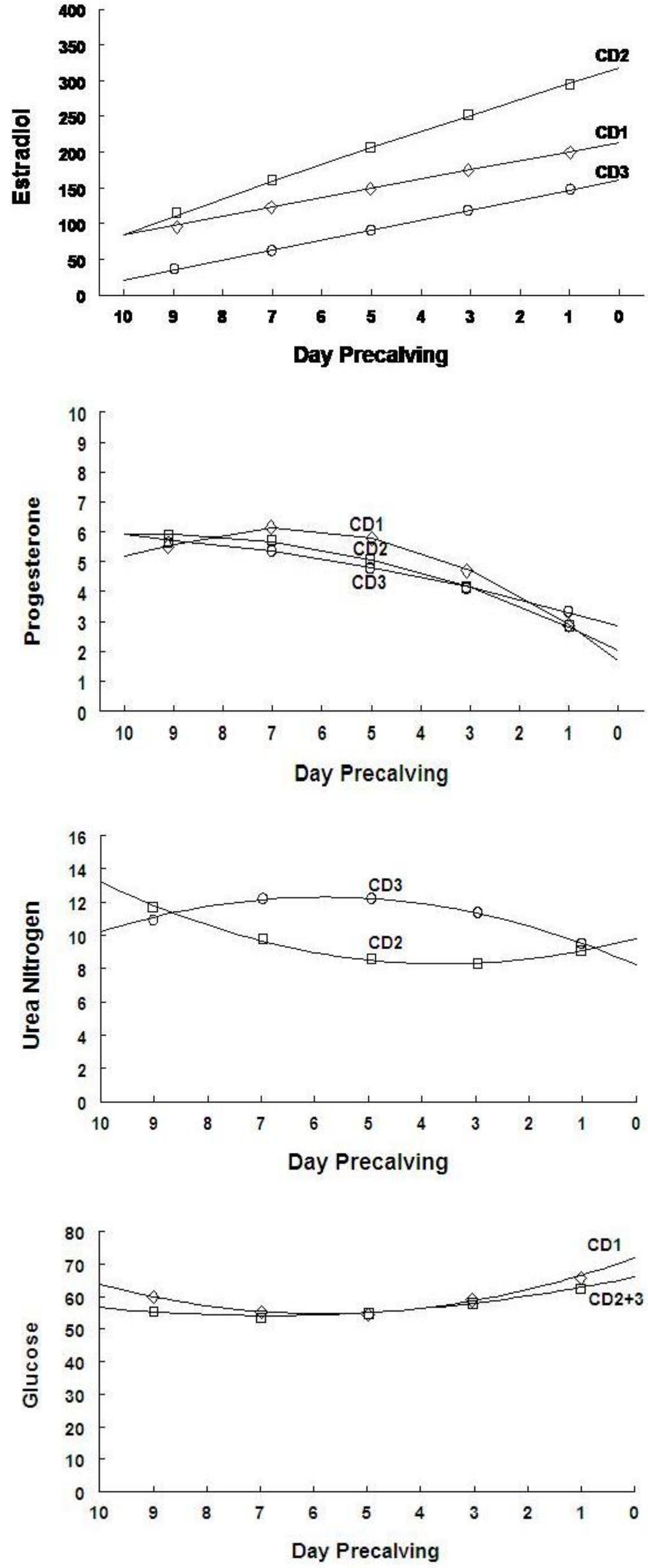


Figure 1. Blood concentrations of compounds before calving shown by calving difficulty score.

calving and those that did not. Thus, steroid hormone profiles and blood metabolites seem related to calving difficulty.

Future Direction: Results of this work are considered definitive. Resources have been redirected to studies on effects of dietary fat on calving difficulty, calf survival, and rebreeding of the dam.

Relevant Publications: Anthony, R.V., R.A. Bellows, R.E. Short, R.B. Staigmiller, C.C. Kaltenbach, and T.G. Dunn. 1986. Fetal growth of beef calves. I. Effect of prepartum dietary crude protein on birth weight, blood metabolites and steroid hormone concentrations. J. Anim. Sci. 62:1363-1374.

Bellows, R.A. 1995. Managing the first-calf heifer. Proc. International Beef Symposium Montana State University, Department of Animal and Range Science. Special Report SR58. p. 74-85.

Body Temperature and Hormone Interactions Before and After Calving in Beef Cows

M.A. Lammoglia and R.A. Bellows

Problem: About 64% of calf deaths that occur during the first 96 hours after calving are due to calving difficulty. One-half of these losses could be avoided by timely and correct obstetrical assistance. Knowing when the calving sequence starts may aid in determining when to give obstetrical assistance and result in increased calf survival.

The cow's body temperature decreases 8 to 28 hours before calving. Thus, body temperature before calving may be useful to predict time of calving. The goal of this study was to evaluate body temperature as an indicator of time of calving.

Procedures: Seven mature crossbred beef cows with known breeding dates were used in this study. Cows calved without difficulty during the summer and the average environmental temperature was 69 °F. Cows were kept in drylots and fed a corn silage diet.

Electronic body temperature monitors[1] were implanted surgically 15 to 18 days before calving and were removed 48 to 96 hours after calving. Body temperature was recorded via radio-telemetry for 10 seconds every 3 minutes. Environmental temperature data was obtained from a laboratory weather station.

Findings: Before the prepartum decrease (Figure 1), the cows' body temperatures were affected by calf sex and environmental temperature. After calving, body temperature was affected only by environmental temperature. In contrast, the precalving decline in body temperature was not affected by either sex of calf or environmental temperature.

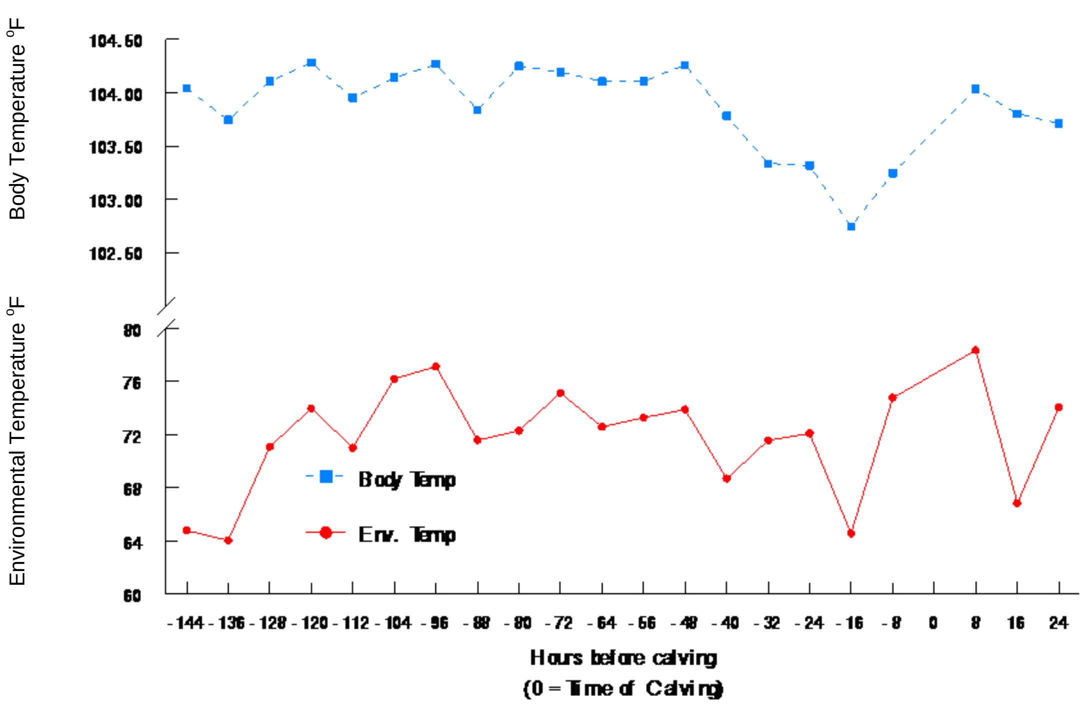


Figure 1. Body and environmental temperatures as related to time of calving.

[1] Minimitter, P.O. Box 3386, Sun River, OR 97707.

Decreased body temperature in the dam before giving birth may be involved in triggering calving. It may also cause an increase in fetal temperature by inducing a compensatory mechanism for body temperature rise in the calf to compensate for the temperature loss that occur at birth in the newborn. However, additional work is needed before this temperature drop can be used to predict time of calving.

Future Directions: This work is continuing. Studies are focused on determining relationships of body temperature with calf survival and subsequent reproduction in the dam.

Relevant Publications: M.A. Lammoglia, R.A. Bellows, R.B. Staigmiller, R.E. Short, S.E. Bellows, E.G. Bighorn, D.T. Brophy, J.S. Stevenson, and R.D. Randel. 1996. Peripartum body temperature and hormonal interactions in beef cows. Proc. West. Sect. Amer. Soc. Anim. Sci. 47:209-212.

Do Pine Needles Cause Abortions in Species Other than Cattle and Do Pine Species Other than Ponderosa Cause Abortions?

R.E. Short, E.E. Grings, S. Kronberg, J. Rosazza, and S. Ford

Problem: Cattle producers in the Western United States may experience significant and even catastrophic economic losses when late pregnant cattle abort after eating needles from Ponderosa pine trees. Economic losses occur because calves are born premature and do poorly or die. Affected cows always have retained placentas, and if not treated properly, may cause complications and even death of the cow. Ranchers are not able to use available pastures because of potential losses.

Physiologically, the abortive response is caused by a vasoconstrictive substance (interferes with vasodialation or blood flow) in the pine needles. This substance causes a profound decrease in uterine blood flow. As a result the calf is stressed and induces parturition. Thus, the effect is an induced parturition rather than an abortion. We still refer to the problem as pine needle abortion because the expression is so commonly used. Nonpregnant cows, steers, and bulls are not affected.

The response becomes more pronounced as pregnancy progresses. In the first trimester of pregnancy, very few cows are affected, some will be affected in the second trimester, and almost all cows are susceptible during the third trimester, especially in the last 30 to 60 days. Cows need to eat from 3 to 5 pounds of needles for several days to induce the abortions, and the abortions will stop within 2 to 3 days after the source of pine needles is removed or the cows are removed from the source.

The solution to this problem depends on finding a way to block the effects after the cow eats the needles or by preventing cows from consuming needles. Altering the diet once cows have eaten pine needles has not affected their response. Dietary variables studied have included vitamins, minerals, an organic binder (bentonite), forage (hay, straw, silage, etc.), and concentrates. We can block the induced parturition by feeding a progestin (MGA) or a prostaglandin inhibitor (such as aspirin). However, these treatments only block parturition. They do not correct the underlying problem of a drastic decrease in blood flow to the uterus.

Discouraging cows from eating pine needles in the first place has been equally unsuccessful. The only dietary variable that prevents pine needle consumption is when cows are fed 25% or more corn silage. Why this occurs is not known. However, feeding corn silage is not a practical solution on most farms or ranches where pine needle abortion is a problem. Low protein content of the diet will decrease pine needle consumption, but it will not prevent it. Many other dietary variables have been tested unsuccessfully.

One approach scientists use to understand biological systems is to compare form, function, and responses among species. By comparing differences in response to treatments and differences in physiology, it is often possible to determine the how and why of a biological system or phenomena. In the case of pine needle abortion our goals were to compare different animal species response to pine needle consumption and different species of pine for whether or not they cause the problem. Animal comparisons provide clues to physiological and metabolic mechanisms. Plant comparisons provide clues to the active components.

Procedures: Effects of pine needles on different animal species were studied in feeding trials. Ponderosa pine needles are fed to late pregnant females of different species at the rate of about 25% of their diet. Bos taurus (several European breeds) and Bos indicus (Brahman) cattle, guinea pigs, bison, goats, domestic and bighorn sheep, elk, and whitetail deer were tested.

Pine needles were collected from various species of pine trees, dried and ground. The ground needles were fed to cows in late pregnancy at the rate of 4 to 6 lb/day.

Blood samples were taken before and during feeding to determine physiological effects of pine needle consumption. Interval to parturition was used as an indicator of abortifacient activity.

Findings: Both cattle species have induced parturitions in response to consuming Ponderosa pine needles. Guinea pigs responded similar to cattle. The guinea pig response is now used as a bioassay for activity in pine needles. When pine needles are mixed with their only feed source, bison eat them and abort like cattle. However, several herds of bison in the U. S. graze in areas with Ponderosa pine trees during late pregnancy with no observed abortions or decrease in calving rates. Thus, bison may not normally eat pine needles. Other than providing an assay, these two species do not help much as a model to understand pine needle abortion because they are not different from cattle.

Sheep and goats are partially different from cattle in that they do not abort as do cattle. However, sheep may have an increased incidence of dead fetuses at birth. Both sheep and goats, like cattle, have high vasoconstrictive activity in blood samples taken 3 or 4 days after pine needle feeding starts. This would indicate that the activity passes through their GI tract and is absorbed into the blood just as in cattle. Either the blood flow mechanisms are different or are less responsive in sheep and goats as compared to cattle. Because of this similarity, these two species also have limited usefulness in helping to understand pine needle abortion.

Elk provide an interesting model in that they inhabit areas where Ponderosa pine trees are often prevalent. They eat pine needles and have normal calving rates in the wild. In an experiment where pine needles were mixed with their diet, elk did not abort or have increased vasoconstrictive activity in plasma. How elk deactivate the active material from the pine needles is unknown. When ruminal contents from elk have been incubated in vitro with pine needles the vasoconstrictive activity was destroyed. In companion trials with ruminal contents from cattle there was no decrease in vasoconstrictive activity. In a preliminary experiment, ruminal contents from elk were transferred to pregnant cattle before and during pine needle feeding of the cattle. The elk ruminal contents tended to delay but not prevent the abortive effects of the pine needles.

It is interesting to speculate on why there may be species differences in response to pine needles. Both Bos taurus and Bos indicus cattle evolved in parts of the world where they did not have access to needles from Ponderosa pine trees. Thus they would not have needed to devise a strategy to deal with any adverse effects. On the other hand, many wild species of ungulates evolved in environments with access to these needles. Bison will abort when force-fed pine needles. They apparently evolved a strategy of not consuming them. Elk may need access to pine needles as a nutrient source at some times of the year. Thus, they developed a strategy of inactivating the abortifacient activity. Other species such as deer and bighorn sheep may have evolved the same or by other strategies.

Most research on pine needle abortion has been conducted with needles from Ponderosa pine. All collections that were from Ponderosa pine trees over several years had about equal activity regardless of geographic location, age, on trees or on the ground, and fresh or weathered. Therefore, there is no variation in needles from Ponderosa pine to use as an aid in determining the active ingredient(s).

Collections from other species may be useful to identify potential differences in abortifacient response and associated differences in chemical composition. Data from other pine species would also be useful so that producers can know which of them are or are not potential problems. Loblolly, Lodgepole, Red, and White pine do not have detectable abortifacient activity. Two chemical compounds or classes of compounds have been identified as the culprits in pine needle abortion. However, the data are confusing as to which of the two or some combination is actually involved. These four species of pine that do not cause abortions are being evaluated for their content of these two chemicals. This information will be used to help answer the questions regarding the active ingredient.

Future Directions: Research will continue with elk to determine if the digestive and(or) metabolism differences can be identified and duplicated in cattle. More complete transfer of elk ruminal contents to cattle is needed to determine if elk ruminal microflora can inactivate the abortive effects of pine needles in cattle. If successful, then further research will determine how the abortifacient activity is destroyed and whether there are practical ways to transfer this process to cattle.

Other plant species will be screened to identify potential problems and chemicals.

Relevant Publications: Al-Mahmoud, M.S., S.P. Ford, R.E. Short, D.B. Farley, and J.P. Rosazza. 1995. Isolation and characterization of vasoactive lipids from the needles of Pinus ponderosa. J. Agric. Food Chem. 43:2154-2161.

Bellows, S.E., R.E. Short, and S.P. Ford. 1996. Effects of feeding pine needles to late pregnant elk and goats. Proc. West. Sec. ASAS 47:186-188.

Christenson, L.K., R.E. Short, and S.P. Ford. 1992. Effects of ingestion of Ponderosa Pine needles by late pregnant cows on uterine blood flow and steroid secretion. J. Anim. Sci. 70:531-537.

Christenson, L.K., R.E. Short, J.P. Rosazza, and S.P. Ford. 1992. Specific effects of blood plasma from beef cows fed pine needles during late pregnancy on increasing tone of caruncular arteries *in vitro*. J. Anim. Sci. 70:525-530.

Christenson, L.K., R.E. Short, D.B. Farley, and S.P. Ford. 1993. Effects of ingestion of pine needles (*Pinus ponderosa*) by late-pregnant beef cows on potential sensitive Ca^{2+} channel activity of caruncular arteries. J. Reprod. Fert. 98:301-306.

Ford, S.P., J.P.N. Rosazza, M.S. Al-Mahmoud, D.B. Farley, and R.E. Short. 1997. Use of late pregnant guinea pig to confirm the abortifacient effects of a unique class of vasoactive lipids in *Pinus ponderosa* needles. J. Anim. Sci. 75: (Accepted).

Lacey, J.R., L.F. James, and R.E. Short. Ponderosa Pine: Economic Impact. 1988. In: James, L.F., Ralphs, M.H. and Nielsen, D.B. (Eds.) The Ecology and Economic Impact of Poisonous Plants on Livestock Production. pp. 95-118. Westview Press, Boulder, CO.

Panter, K.E., L.F. James, D.C. Baker, and R.E. Short. Pine needle toxicosis in cattle and goats. 1987. J. Anim. Sci. 65(Suppl. 1):351. (Abs.)

Short, R.E., L.F. James, K.E. Panter, R.B. Staigmiller, R.A. Bellows, J. Malcom, and S.P. Ford. 1992. Effects of feeding pine needles during pregnancy: comparative studies with bison, cattle, goats, and sheep. J. Anim. Sci. 70:3498-3504.

Short, R.E., R.A. Bellows, R.B. Staigmiller, and S.P. Ford. 1994. Pine needle abortion in cattle: Effects of diet variables on consumption of pine needles and parturition response. J. Anim. Sci. 72:805-810.

Short, R.E., R.A. Bellows, R.B. Staigmiller, S.P. Ford, and J. Rosazza. (Bylined by Clint Peck). 1995. Dealing with pine needle abortion. Western Beef Producer. p. 1, 20-21.

Short, R.E., S.P. Ford, E.E. Grings, and S.L. Kronberg. 1995. Abortifacient response and plasma vasoconstrictive activity after feeding needles from ponderosa pine trees to cattle and sheep. J. Anim. Sci. 73:2102-2104.

Short, R.E., R.B. Staigmiller, R.A. Bellows, and S.P. Ford. 1995. Endo-crine responses in cows fed ponderosa pine needles and the effects of stress, corpus luteum regression, progestin, and ketoprofen. J. Anim. Sci. 73:198-205.

Short, R.E., R.B. Staigmiller, R.A. Bellows, K.E. Panter, and L.F. James. 1987. Effect of level and duration of feeding of pine needles on incidence of abortions in cattle, sheep and goats. J. Anim. Sci. 65(Suppl. 1):352. (Abstract).

Short, R.E., R.B. Staigmiller, K.E. Panter, and L.F. James. 1987. Effect of stage of pregnancy on pine needle-induced abortions in cattle. Proc., Can. West. Soc. Reprod. Biol. 9:27. (Abstract).

Heat Production and Endocrine Patterns of Full Term and Premature Calves Born to Fat Supplemented Cows

M.A. Lammoglia and R.A. Bellows

Problem: Calf death loss at or near birth has been estimated to be about nine percent. Seven percent of this mortality is due to cold stress. Thus, about 95,000 calves die each year due to severe cold stress. In addition, calf survival rate may be highly variable among years and states. For example, in 1995 ranchers in the state of Montana lost 57,000 calves. About 40% of these calves died due to calving difficulty and weather conditions. The goal of this study was to evaluate effects of fat supplementation to prepartum beef cows on heat generation(thermogenesis) in full term and premature newborn calves.

Procedures: Study I. Twenty-two, F1, Line 1 Hereford sired heifers bred to an F1, Line 1 Hereford bull were fed either 1.7% (Low fat; LF) or 4.9% (High fat; HF) dietary fat. Safflower seeds containing 37% oil with 80% linoleic acid were used as the source of fat. Rations were formulated to be equal in energy and protein levels and sufficient for the heifers to gain 1 pound daily. These diets were fed from day 230 of gestation until calving.

Within 20 minutes after calving and before nursing, newborn calves were weighed and fed pooled colostrum with an esophageal tube. The calves were then returned to their dams in a heated (71 °F) barn for 3.5 hours.During this time nursing was prevented by muzzling the calves. At 5 hours after

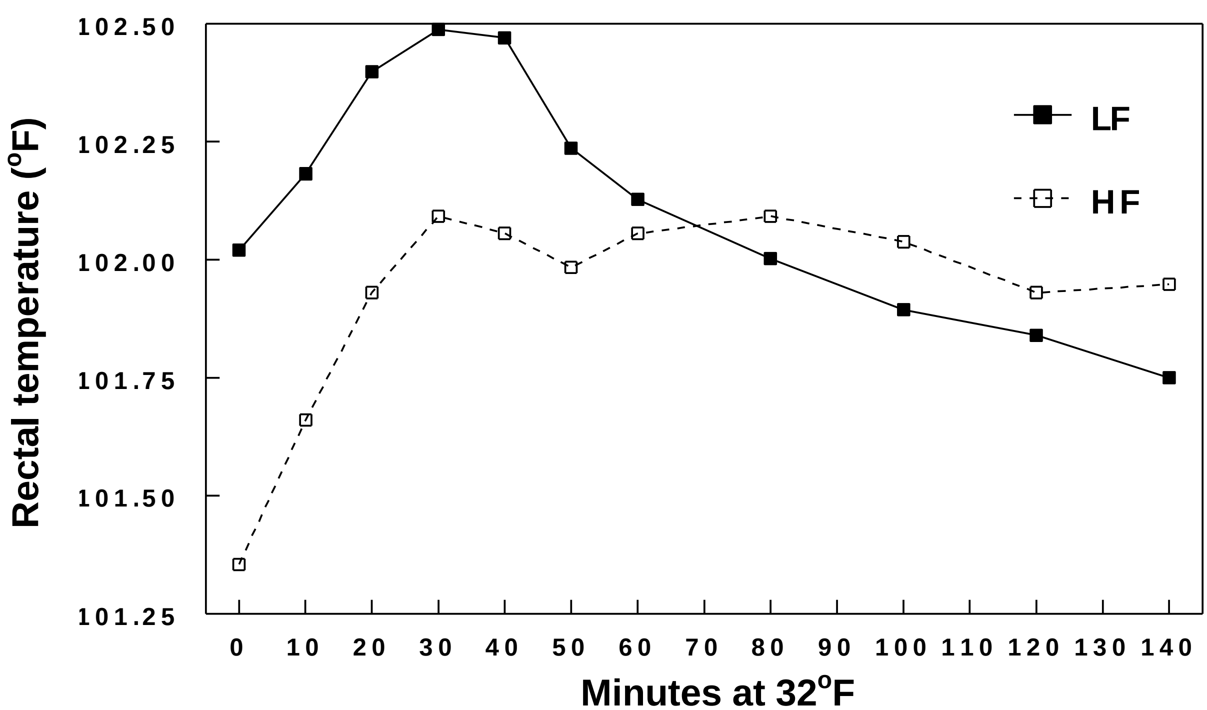


Figure 1. Rectal temperature of newborn calves exposed to 32°F for 140 minutes and born to cows receiving 1.7% (LH) or 4.9% (HF) dietary fat 53 days before calving.

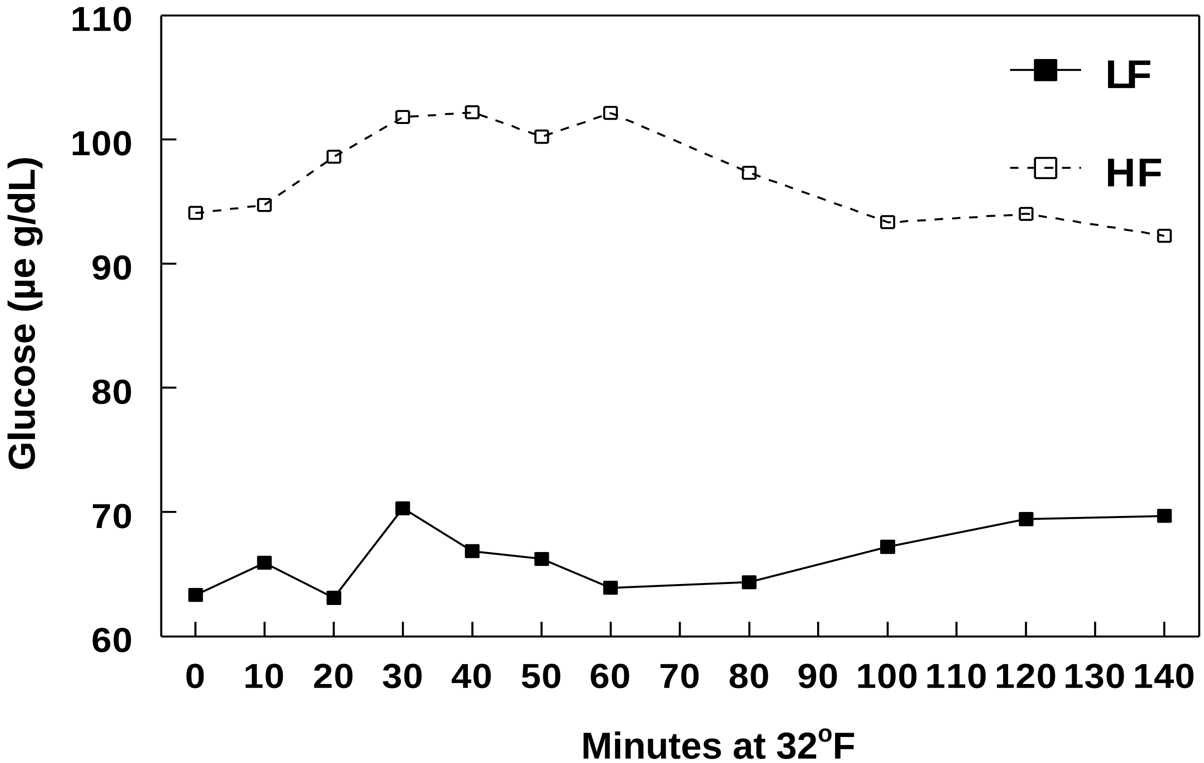


Figure 2. Plasma glucose concentrations of newborn calves exposed to 32°F for 140 minutes and born to cows receiving 1.7% (LH) or 4.9% (HF) dietary fat 53 days before calving.

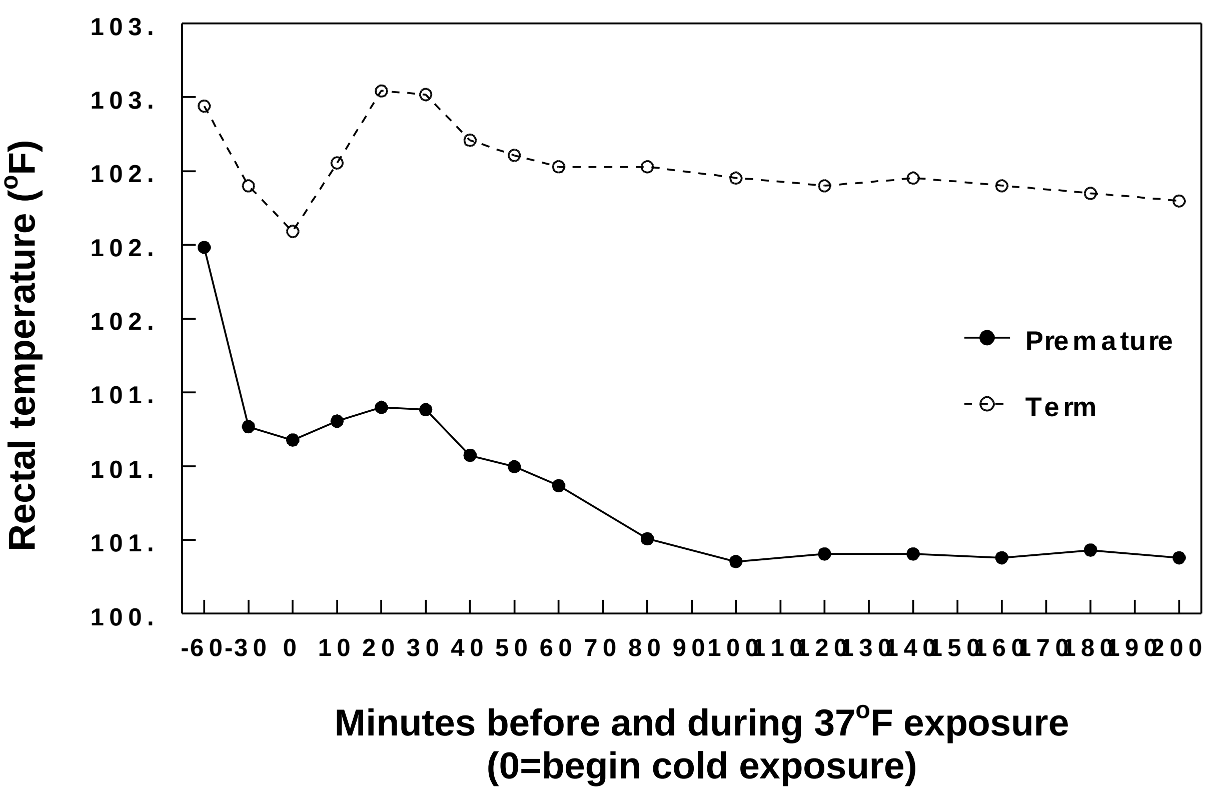


Figure 3. Rectal temperature of newborn mature and premature calves exposed to 37°F for 200 minutes.

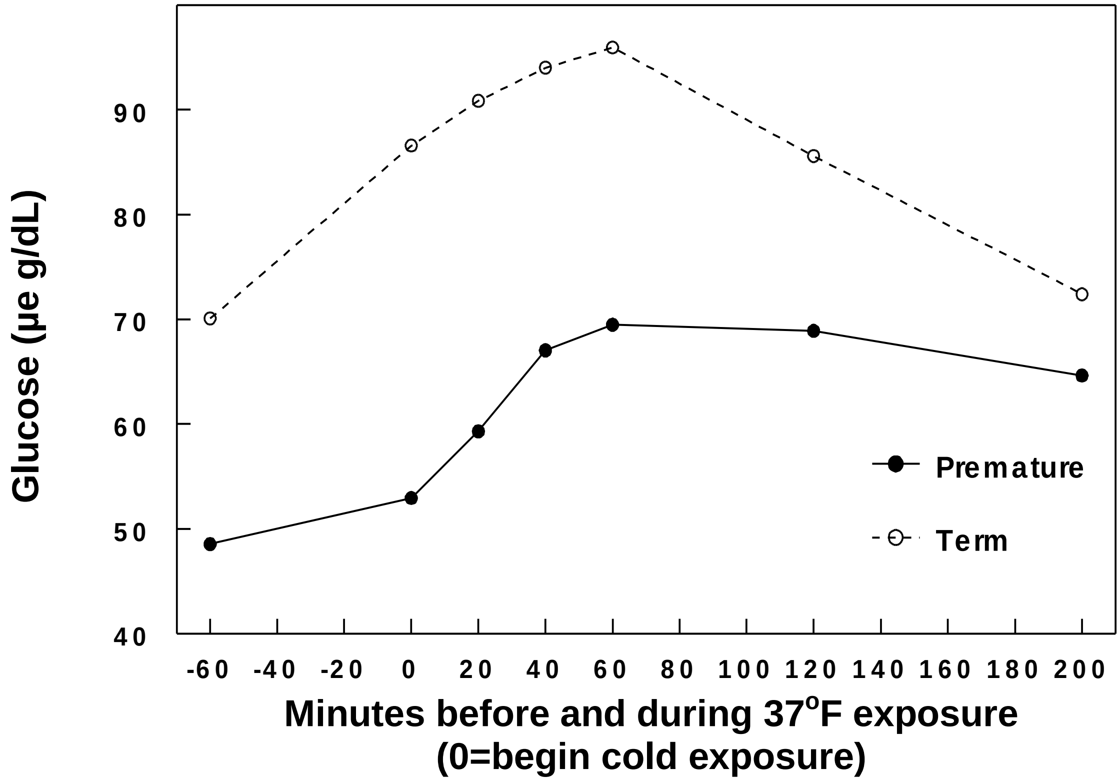


Figure 4. Plasma glucose concentrations of newborn mature and premature calves exposed to 37°F for 200 minutes and born to cows receiving 1.5% (LF) or 3.4% (HF) dietary fat 28 days before calving.

birth the calves were placed in a 32°F room for 140 minutes. Rectal temperatures measurements and blood samples were taken periodically for 140 minutes.

Study II. Twenty-three mature crossbred beef cows were artificially inseminated to Murray Grey sires. Starting at 235 days of pregnancy, cows received either 1.5% (Low fat; LF) or 3.4% (High fat; HF) dietary fat. Safflower seeds containing 37% oil with 80% linoleic acid were used as the source of fat. Rations were formulated to be equal in energy and protein and sufficient for cows to gain 1.1 pounds daily.

At day 260 of pregnancy, cows were fed either 0 or 4.4 pounds of pine needles. Cows receiving pine needles calved prematurely within 5 days (prematurecalves). Cows receiving no pine needles carried their calves to term (283 day; term calves).

Within 20 minutes after calving and before nursing, newborn calves were weighed and fed pooled colostrum with an esophageal tube. Afterwards calves were maintained in a 71 °F room for one hour. Rectal temperatures were taken periodically for 200 minutes.

Findings: Feeding 4.9% dietary fat during the last 53 days of pregnancy improved heat production (Figure 1) and increased plasma glucose concentrations in newborn calves (Figure 2). Increased plasma glucose concentrations may improve heat production and potentially survival when exposed to cold conditions.

Feeding fat for the last 28 days of gestation was not enough to alter heat production of newborn term or premature calves exposed to 37 °F. Premature calves had lower blood glucose concentrations than term calves (Figure 3) and premature calves were also cold intolerant (Figure 4).

Future Directions: This work is continuing. The studies are focused on the potential for feeding fat to increase calf survival.

Relevant Publications: M.A. Lammoglia and R.A. Bellows. 1996. Effects of nutrition and cow temperature before calving on heat production in the new born and survival rate. Proc. Governor's Conf. on the State of the Cattle Industry. Billings, MT. p 66-69.

Further Studies on the Effect of Feeding Fat to Pregnant Heifers on Cold Tolerance of Their Newborn Calves

M.A. Lammoglia and R.A. Bellows

Problem: The problem of death loss in newborn calves has an important economic impact on profitability for the beef producer. This study is a continuation of our work designed to determine the effects of fat supple-mentation of the gestation diet on cold tolerance of the newborn calf.

Procedures: Effects of feeding preg-nant dams supplemental dietary fat during the last 55 d of gestation on cold tolerance of newborn crossbred calves was studied in Piedmontese cross (P, n = 15) or Hereford cross (H, n = 16) calves. First-calf F1 dams gestating F2 calves of the respective breeds were assigned within breed to receive gestation diets containing either 2.2% (Low Fat; LF) or 5.1% (High Fat; HF). Safflower seeds containing 37% oil with 79% linoleic acid were the supplemental fat source in diets formulated to be isocaloric-isonitrogenous. At calving, calves were separated from their dams, fed 100^{o}F pooled dairy cow colostrum, muzzled to prevent suckling, and returned to their dams in a heated (72^{o}F) room for 3.5 h. At 4 h of age (birth = 0 h), a catheter was inserted into the jugular vein. At 5 h of age, calves were placed in a 32^{o}F room for 140 min and rectal temperatures and blood samples were obtained at 10 and 20 min intervals.

Findings: Calves from HF dams had higher rectal temperatures (P<.01) than calves from LF dams, and the HF calves maintained higher rectal temperatures throughout cold exposure (Figure 1). Calves from HF dams had more (P = .06) glucose available for metabolic heat production than calves from LF dams (Figure 2). Piedmontese-cross calves maintained higher (P < .01) rectal temperatures and had higher glucose (P < .01, Figures 3 and 4) concentrations than did H-cross calves. We conclude that feeding the dam supplemental fat during late gestation increased heat production in the new born calf and potentially could increase calf survival; calves with muscle hypertrophy

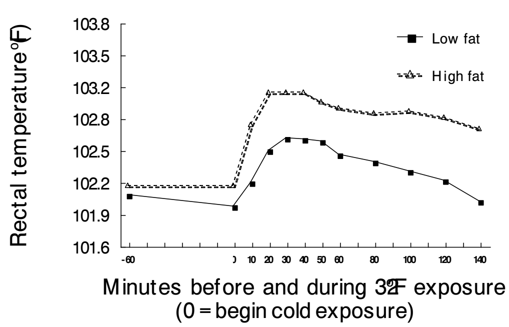


Figure 1. Rectal temperature of newborn calves exposed to 32^{o}F for 140 min and born to cows receiving 2.2% (LF) or 5.1% (HF) dietary fat for 55 d before calving (P<.01).

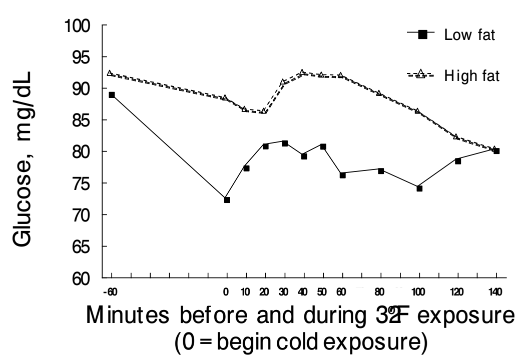


Figure 2. Plasma glucose concentrations of newborn calves exposed to 32^{o}F for 140 min and born to cows receiving 2.2% (LF) or 5.1% (HF) dietary fat for 55 d before calving (P=.06).

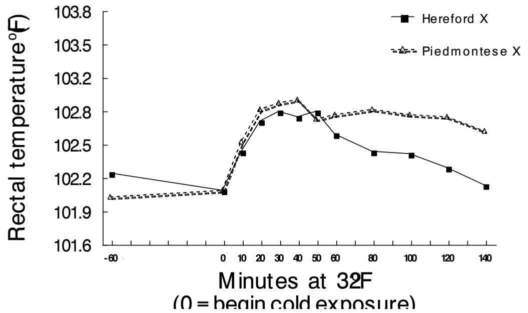


Figure 3. Rectal temperature of newborn Hereford-cross or Piedmontese-cross calves exposed to 32°F for 140 min (P<.01).

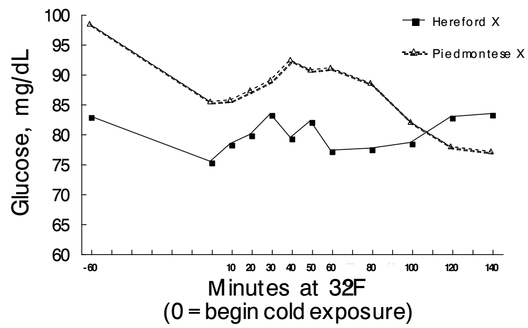


Figure 4. Plasma glucose concentrations of newborn Hereford-cross or Piedmontese-cross calves exposed to 32°F for 140 min (P<.01).

(Piedmontese-cross) may have a different ratio of shivering vs. non-shivering thermogenesis due to differences in body composition or relationships among uncoupling proteins.

Future Directions: This work is continuing. The studies are focused on the potential for feeding fat to increase calf survival.

Relevant Publications: Lammoglia, M.A., R.A. Bellows, E.E. Grings, J.W. Bergman, R.E. Short, and M.D. MacNeil. 1999. Effects of feeding beef females supplemental fat during gestation on cold tolerance in newborn calves. J. of Anim. Sci. 77:824-834.

Lammoglia, M.A., R.A. Bellows, E.E. Grings, and J.W. Bergman. 1999. Effects of parpartum supplementary fat and muscle hypertrophy genotype on cold tolerance in the newborn calf. J. of Anim. Sci. 77:(In press).

Effects of Feeding Supplemental Fat During Gestation on Reproduction in First-calf Beef Heifers

R.A. Bellows, D.D. Simms, E.E. Grings, D.A. Phelps, S.E. Bellows, N.R. Bellows, R.E. Short, R.N. Funston and T.W. Geary

Problem: Finding ways to increase pregnancy rate in lactating beef heifers is important because this age group of females routinely has a low pregnancy percentage. Our previous work has shown this is the result of the nutrient demands on the heifer. She is lactating, growing, recovering from calving, and still must come in heat and breed. Having diets that are adequate in protein, energy, min-erals, and vitamins are necessary if all these demands are met. This study was conducted to determine if feeding supplemental vegetable fat in the gestation diet would have effects on rebreeding of lactating beef heifers.

Procedures: First-calf crossbred beef heifers (n = 149) calving in three calving seasons (February, April, or June) were assigned randomly to one of four gestation diets: control or added safflower seeds, soybeans, or sunflower seeds. Oil seeds were processed through a roller mill to crack hulls in approximately 90% of seeds but without oil loss. Diets were approximately isocaloric-isonitrogenous and contained 2.0, 4.2, 3.3, or 4.5% fat, respectively. Diets were group fed in dry lot and were fed for an average of 65.3 days precalving.

Heifer weights and body condition scores (1-10) were obtained throughout the study; estrous cycling activity was based on progesterone content of blood samples obtained at begin breeding; pregnancy was determined by ultrasound at 60-90 days following 35-37 days breeding seasons. Estrus was synchronized with a single injection of prostaglandin. Calf data included birth weight, calving ease, sex, and weaning weight.

Table 1. Effects of fat supplementation on dam pregnancy and calf weaning weights.[a]

Diet or fat source	No. heifers	Lb oil seeds fed daily	Diet % fat	Fall: Pregnancy %	Fall: Calf wt,lb
Control	33	-	2.0	79	402
Safflower seeds	32	2.8	4.2	94	427
Soybeans	31	6.5	3.3	90	435
Sunflower seeds	36	2.8	4.5	91	434
				0.13% (P<.05)	+30 lb (P=.09)

[a] Data pooled from Feb., April, and June calving seasons.

Findings: Effects of fat supplementation on dam weight or condition scores throughout the study were nonsignificant as were effects on birth weight, calving ease, and dam estrous cyclicity at begin breeding. Heifers from fat supplemented groups had greater pregnancy rates (P<.05) and calf weaning weights (P=.09) (Table 1).

We conclude fat supplementation of the gestation diet in first-calf heifers resulted in positive increases in dam pregnancy rates and tended to increase calf weaning weights.

Future Direction: The work will continue to determine when and how much supplemental fat is needed to result in increased pregnancy rates. We will also be studying what mechanisms control this phenomenon.

Relevant Publications: Bellows, R.A., D.D. Simms, E.E. Grings, D.A. Phelps, S.E. Bellows, N.R. Bellows, R.E. Short, R.N. Funston and T.W. Geary. 1999.

Effects of feeding supplemental fat during gestation on reproduction in primiparous beef heifers. J. of Anim. Sci. 77. (In press). Abstract.

E. Genetic Improvement

Genetic improvement is made by selecting animals for breeding that are above average in production traits of interest. These traits need to be measurable and heritable. Technologies exist to aid producers in making genetic improvement. For example, selection indices have been in use for 60 years. Recent technological advances, however, have provided new and powerful tools to aid in making selection decisions. Increases in computer power have allowed for advances in data storage, handling, and manipulation. Rapid advances in understanding the genome have allowed the use of marker assisted selection, allowing for rapid and accurate identification of superior animals.

Selecting Beef Cattle to Genetically Increase Profit

M.D. MacNeil and S. Newman

Problem: The selection problem, that of choosing which bull and heifer calves become parents, exists for all of beef production. This problem almost always involves evaluating animals for more than one trait. It requires making trade-offs among traits to arrive at a final evaluation of each candidate for selection. Genetic potential for profit seems a logical basis for that final evaluation. It can be assumed that beef producers seek to increase profit.

Most genetic change is made by seed-stock breeders and consumers are implicit customers of the entire industry. Commercial producers, feedlot operators and others are intermediaries in the production system. Thus, seedstock selection decisions should be based on ultimate customer satisfaction. It is less useful for seedstock breeders to base their selection decisions on their own needs or on those of the cow-calf producers that buy bulls from them. The goal of this paper is to illustrate methods that can be used by seedstock breeders to genetically increase profit for the beef industry.

Procedures: Selection index is a tool that can be used to evaluate animals for their potential to increase profit. The following steps are useful in arriving at this goal.

Step 1 is to determine the economically important traits and the relative value of each of them. This requires a sound and complete description of a beef production system. A computer simulation model is a useful tool for this purpose. With the model, changes in profit that occur when changing one trait by itself holding all other traits constant can be estimated. These changes in profit are referred to as relative economic values for the traits. At this point whether or not the trait can be measured is not a consideration. The only concern is with finding the traits that are important and computing their contribution to profit from the production system. For example, about β the cost of cow-calf production stems from feed required by the cow-herd. Yet feed intake is very costly and difficult to measure on each cow. Even so feed intake can be one of the important traits to consider in making selection decisions.

Step 2 is to choose the selection criteria. They should be easy and affordable to measure and have close genetic ties to the economically important traits. Selection criteria are ideally also measured early in life and without having to sacrifice the calf. For example, scrotal circumference (SC) in yearling bulls has little economic value in its own right. However, age at puberty in heifers can be economically important. It is easy to measure SC accurately and the genetic correlation between it and age at puberty in heifers is quite high. Thus, SC can be a useful trait to consider in selection when age at puberty in heifers is economically important.

Step 3 is to optimize the data recording scheme. The data recording scheme needs to be optimally structured to facilitate genetic evaluation. For instance, genetic evaluations for reproductive traits and longevity are not possible if the data recording scheme is based on calf records. This results because data for cows that do not have calves are not reported. Accounting for every cow in the inventory can be the

Step 4 is to use recorded data to evaluate candidates for selection. Selection index methods that were developed over 60 years ago remain a viable means for bringing together the selection criteria and economically important traits. The math can be easily done using a personal computer and a specialized computer program. The resulting formula can be used to calculate expected progeny differences (EPD) for profit.

Step 5 is to use for breeding those animals that were found to have greatest genetic potential for profit. All too often EPD are carefully developed through the production of expected progeny differences, only to become a marketing tool. Failure to use for breeding those animals that were evaluated as having greatest potential to increase profit reduces the rate of genetic improvement.

Example: In *step 1* two traits, net reproduction (NR) and carcass merit (CM) are identified as controlling major changes in profit. Further, NR is found to be 20-fold more important than CM.

Hence, Profit = 20NR + 1CM.

Only in the interest of simplicity has feed intake not been included in this example. As discussed earlier, it is important to the cost of producing beef. It should be included in the index to be used for actual genetic evaluation.

In *step 2*, three traits, birth weight (BW), yearling weight (YW), and scrotal circumference (SC), may be useful as selection criteria. All three are easy to

root of a more nearly optimal data recording system.

measure early in the life of bull calves. Birth weight has a moderate to high genetic correlation (r_g) with CM, especially the weight component. Birth weight also has a low to moderate r_g with net reproduction, arising mainly through the association of birth weight with calving difficulty. In this example, YW is not related to NR. This is due to BW being held constant in determining the relative economic value of YW. However, YW has a high r_g with the weight component of carcass merit. Finally, SC has a moderate to high r_g with NR as discussed previously. It also has a low to moderate r_g with CM arising from the r_g of carcass quality and early maturity.

This example highlights one of the problems with data recording schemes that are not optimally organized. In earlier comments about organizing data recording systems (*step 3),* inventory based schemes were favored over those that are progeny based. If there were an inventory based scheme in place, it would be simple to include a direct measure of NR on many of the female ancestors of the yearling bulls being evaluated. This would greatly improve the accuracy of their genetic evaluation for profit potential.

How should the performance data be evaluated as indicated in *step 4*? Needed information can be obtained for estimates of phenotypic variance (or standard deviations), heritability and genetic and phenotypic correlations reported in the scientific literature. If enough data is available from the population being evaluated, these statistics may be calculated expressly for this population. Given these genetic statistics and without going into detail, the number crunching is performed using a specialized computer program. The weighting factors that maximize profit given the performance data are: for BW -0.034, for YW 0.068, and for SC 0.193.

Then consider 5 candidates for selection with these records:

Bull no.	BW	YW	SC
93502	90	1012	34
93552	99	1087	36
93452	70	1021	33
93469	97	1069	36
93507	88	1208	38

Their evaluations for profit potential are:

Bullno.	Evaluation	Rank
93502	-0.034(90) + 0.031(1012) + 0.193(34) = 35.1	5
95552	-0.034(99) + 0.031(1087) + 0.193(36) = 37.3	2
93452	-0.034(70) + 0.031(1021) + 0.193(33) = 35.6	4
93469	-0.034(97) + 0.031(1069) + 0.193(36) = 36.8	3
93507	-0.034(88) + 0.031(1208) + 0.193(38) = 41.8	1

Despite their quite different levels of performance for each trait, the first 4 bulls have quite similar genetic evaluations for profitability. The fifth bull (93507) appears quite clearly superior to the others. This example also serves to illustrate compromising superiority in one trait with inferiority in another resulting in a consistent overall evaluation of genetic merit.

The same bulls evaluated previously using their phenotypic information also had EPD calculated as part of a national cattle evaluation (NCE). Interestingly, the selection index weighting factors for the EPD turn out to be exactly the same as for the performance records. Thus, given the EPD below

Bull no.	BW	YW	SC
93502	+0.3	42.	+0.0
93552	+1.6	50.	+0.6
93452	-4.4	34.	-0.2
93469	+1.0	50.	+0.3
93507	+0.5	53.	+0.5

their evaluations for potential contributions to profitability are:

Bull no.	Evaluation	Rank
93502	-0.034(0.3) + 0.031(42) + 0.193(0.0) = 1.29	4
95552	-0.034(1.6) + 0.031(50) + 0.193(0.6) = 1.61	2
93452	-0.034(-4.4) + 0.031(34) + 0.193(-0.2) = 1.17	5
93469	-0.034(1.0) + 0.031(50) + 0.193(0.3) = 1.57	3
93507	-0.034(0.5) + 0.031(53) + 0.193(0.5) = 1.72	1

If NCE were available for NR and CM, then the weighting factors applied to the EPD for NR and CM are the relative economic values themselves.

The ranking of these bulls is substantially the same using a selection index of EPD as they were using a selection index of phenotypes. However, there has been some re-ranking of individuals and 93507 does not appear to be as outstanding as he was based on the phenotypic index. Because data from relatives are used in the EPD, it is a more accurate indicator of genetic merit than individual performance records. Thus, the evaluation based on EPD is preferred.

Future Directions: Making selection index more easily available to seedstock breeders and commercial producers is an ongoing effort. Using breeds as sire and dam lines and capturing heterosis may alter relative economic values from those derived for straightbred production. Because efficient production requires exploiting heterosis, relative economic values for purebred seedstock should be derived from models that include crossbreeding. In the more distant future, we hope to validate these selection indexes using these methods in selection experiments.

Relevant Publications: Enns, R.M., M.D. MacNeil, S. Newman, and J. Stewart-Smith. 1992. Relative economic values for specialized sire and dam lines in Canada. J. Anim. Sci. 70(Suppl 1):96.

MacNeil, M.D., S. Newman, R.M. Enns, and J. Stewart-Smith. 1992. Temporal variation in relative economic values for

MacNeil, M.D. and S. Newman. 1994. Selection indices for Canadian beef production using specialized sire and dam lines. Canadian J. Anim. Sci. 74:419-424.

Newman, S. and M.D. MacNeil. 1993. Selecting beef cattle for genetic improvement in profitability. In: R. K. Heitschmidt (ed.) Research and Range-land Agriculture: Past, Present, and Future. Miles City, MT. p. 44-49.

MacNeil, M.D. 1994. On what to base future genetic improvement? American Hereford Journal, p. S24-S25.

Newman, S., M. MacNeil, B. Golden, and S. Barwick. 1994. Implementation and use of selection indexes in genetic evaluation schemes for beef cattle. In: Proc. Genetic Prediction Workshop, 11 pages. Kansas City, MO.

MacNeil, M.D. 1994. On what criteria to base future genetic improvement?

specialized sire and dam lines in Canada. J. Anim. Sci. 70(Suppl. 1):140.

Newman, S., M.D. MacNeil, and C.A. Morris. 1992. Accounting for food costs in the breeding objective. J. Anim. Sci. 70(Suppl. 1):150.

Enns, R.M., M.D. MacNeil, S. Newman, and J. Stewart-Smith. 1992. Relative economic values for specialized sire and dam lines in Canada. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:124-126.

MacNeil, M.D., S. Newman, R.M. Enns, and J. Stewart-Smith. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. Canadian J. Anim. Sci. 74:411-417.
Western Stock Grower, p 3-5.

MacNeil, M.D. 1995. Using Expected Progeny Differences to improve profitability. IN: Proc. International Beef Symp. Great Falls, MT, p. 190-194.

MacNeil, M.D. and R.A. Nugent. 1996. Concepts relating genetic improvement to profitability and their use in the swine industry. Proc. of the Beef Improvement Federation. p 153-158.

MacNeil, M.D. and D.D. Kress. 1996. Genetic strategies to reduce production costs and improve profitability. Proc. Governor's Conference on the State of the Cattle Industry. Billings, MT. p 77-81.

"Marker Assisted Selection" Made Easy

M.D. Grosz

What are Chromosomes, Genes, and Alleles?

Nearly every cell of an organism contains an entire complement of genetic material in the form of chromosomes. Chromosomes come in pairs (one having been received from each parent), and consist of long stretches of -deoxyribonucleic acid (DNA). The shape of the DNA is a double helix, and the "rungs" on the ladder are called "base pairs" (Figure 1). Each base is one of four possible molecules (Guanine, Adenine, Thymine, or Cytosine; G, A, T, or C).

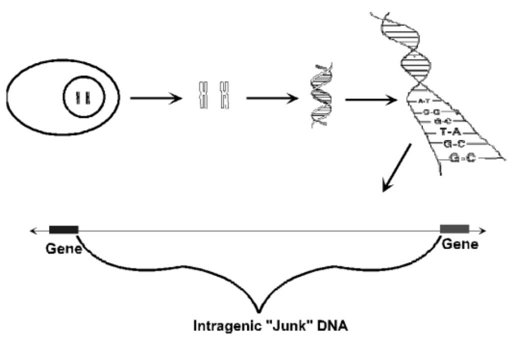


Figure 1. Structures of DNA. Intragenic DNA (DNA whose function is, as of yet, unknown) makes up about 99% of all DNA.

The "blueprint" of an animal is contained in the sequence of bases along the chromosome. Cellular enzymes can read this code and use that information to create other cellular proteins, which will either be used by the cell or secreted for use elsewhere in the body. The term "**gene**" loosely refers to the set of instructions required for the production of one protein. Each gene has an assigned position along the chromosome called a **locus**.

A typical gene may consist of about 5,000 base pairs. It has been estimated that there are approximately 3 billion base pairs, encoding more than 100,000 genes, in the bovine genome. Cattle cells contain 30 pairs of chromosomes and each chromosome may code for as many as 10,000 genes. Genes make up about 1% of all DNA. The remainder of the DNA (99%) has no known function, yet it remains for some reason not yet understood (therefore, it is called "junk DNA").

Any base sequence differences in a gene may result in the production of a different form of a protein. This variant form of a gene is called an "**allele**" (Figure 2). The function of an allele will be the same, but, because of the sequence difference, it may not be able to perform that function as efficiently.

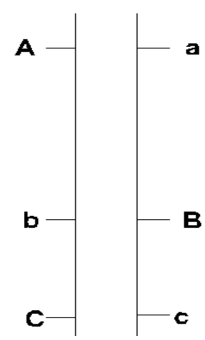


Figure 2. A hypothetical pair of chromosomes with 3 genes (AA,≅ AB,≅ and AC≅) and two alleles for each gene (uppercase and lowercase).

Since genes are the "blueprint" for the production and maintenance of an organism, any sequence differences in the "blueprint" may cause a difference in the animal. By ob-serving traits, we can see the influence of different alleles, as well as their transmission from parent to offspring. There are generally two types of traits: "**simple**" traits, which are determined by differences in a single gene (horned/polled); and "**complex**" traits, which are deter-mined by more than one gene (birth weight). Complex traits are almost always also affected by the environment. Complex traits are also known as "quantitative" traits, since the phenotype can usually be scored along a continuum. A gene that affects a quantitative trait is, there-fore, called a "**QTL**" (Quanti-tative Trait Locus). If the quantitative trait is one that has economic importance, that gene may also be called an "**ETL**" (Economic Trait Locus).

Cell Division

The production of germ cells through meiosis provides an important mechanism that can be used to measure distances between genes. Each germ cell must contain only one of each chromosome, so that after fertilization, the embryo will again contain a pair of each chromosome. Genetic recombination is a process which provides maximum genetic variation between animals. During gametogenesis, maternal and paternal DNA is randomly exchanged to produce a hybrid chromosome which contains both maternal and paternal alleles.

Recombination is an important process for two reasons. First, it increases the amount of variation in a population, since new combinations of alleles are constantly being produced. Second, recombination allows a system to measure distance between two genes. This system uses the frequency of recombination between two genes as the distance. If two genes are very close together, there is very little recombination between them, and they are said to be "**linked.**"

What is a Marker?

In order to study recombination, we must be able to distinguish between different alleles. If there are different alleles for a particular locus, that locus is called "**polymorphic**." If there is no variation, and the sequence of a locus is identical in all animals, that locus is called "**monomorphic**." With an infinite number of alleles for each of more than 100,000 genes, it is easy to understand the incredible diversity that exists within a population.

A "**marker**" is simply a reference point along the chromosome where we know that there is significant polymorphism. Markers become more powerful as linkage relationships between many markers are identified. Developing linkage maps is similar to "connect the dots" to create a picture; as more markers are identified, linkage relationships between markers are discovered, and groups of linked markers are placed on linkage maps.

There are two types of markers: **pheno-typic**, which represent physical differences caused by differences in the DNA sequence (blood type, horn/polled), and **genotypic**, which represent differences in the actual DNA itself (molecular markers). The first types of markers used in linkage experiments were phenotypic markers (coat color and eye structure in mice). However, with the development of technology, new kinds of markers have been developed that allow us to look directly at the DNA.

Genotypic markers can exist either within a gene or in intragenic DNA. Since we know that there is more polymorphism between genes, markers from intragenic DNA generally make better markers.

What is "Gene Mapping?≅

It is known that each animal can only pass one allele for each gene to its offspring. The goal is to determine which (of the two possible alleles) were passed. Markers are used to reach that goal. When we see the inheritance of a marker from parent to offspring, we know that, in addition to the marker, DNA flanking the marker was also passed to the offspring. For mapping simple traits (those controlled by a single gene), we can associate the inheritance of a particular marker allele with the inheritance of the simple trait in close to 100% of the cases. The result of such a study would identify which marker is closest to the gene which controls the trait, thereby Amapping≅ the gene which controls the trait. However, if the gene affects a complex trait, there is much more "noise" (effects of other genes and the environment). Nevertheless, statistical associations can be found between inherited markers and averages for a complex trait if enough animals are surveyed.

What is "Marker Assisted Selection?≅

Marker assisted selection is simply the process of using genetic information (gleaned from using markers) to assist in decisions regarding which animals will be used for producing the next generation.

There are three major advantages to using marker assisted selection over traditional methods: 1) animals can be objectively typed for markers. There are no "judgment calls" or other subjective measure; the test is as simple and more precise than blood typing; 2) typing can be done at birth (or sooner), eliminating the problem of breeding an animal after it has been slaughtered; and 3) typing for markers can be done in either sex, elim-inating the problem of determining sex-limited trait measurements. It has been estimated that by exploiting marker assisted selection, genetic improvement in livestock populations can be increased 5-20%.

Summary

The primary purpose of QTL mapping is the identification of alleles which improve the merit of an animal. In order to achieve this goal, populations must be established which contain different alleles at marker loci <u>and</u> QTLs. This can be accomplished by crossing widely divergent breeds of cattle (*Bos taurus* x *Bos indicus*, for example). However, the application of the resulting knowledge to the Northern Great Plains would be limited, due to the limited numbers of *Bos indicus* animals currently present in commercial production herds in the Northern Great Plains. Because the identification of QTLs is both time and labor intensive, research projects must be carefully planned to maximize the amount of useful information that can be obtained in a cost-effective manner. On one hand, one should strive to identify those alleles which will have the greatest effect on the genetic merit of an animal. On the other hand, one must also strive to find beneficial alleles which may already be well penetrated in the current production herds, effectively speeding up the implementation of marker assisted selection.

Marker assisted selection will be used to identify which animals have inherited advantageous (or detrimental) alleles quickly and reliably. The technology necessary for the widespread implementation of this procedure is already well understood. The bottleneck, at this point, is the identification of markers which are linked to advantageous/detrimental alleles. As this information accrues, marker assisted selection will be used (complimentary to other systems which estimate genetic merit of an animal) to further improve the information available to a breeder making selection decisions.

Use of Markers at Fort Keogh

A search for important genetic markers associated with production traits in the Line 1 Hereford population is underway as part of the current research program at Fort Keogh Livestock and Range Research Laboratory. This research has brought major changes to the traditional selection experiments done at Fort Keogh. In order to identify those alleles coming from Line 1 that make a significant contribution to the level of a production trait requires that crosses be made between Line 1 and a population which does not possess the candidate allele. We chose to make these crosses with our CGC composite population (2 Red Angus, 3 Charolais, and 3 Tarentaise). Preliminary results indicate there is enough genetic difference between these two populations to result in a powerful experiment.

The basic design of the Fort Keogh QTL experiment involves two generations of reciprocal backcrosses. Relative performance of the backcross calves is associated with the inheritance of Line 1 or CGC alleles from the F1 bull. In the end, the relative value of both alleles as they affect the various production traits is determined. If one marker allele is greatly favored over the other, these results can serve as the basis for marker assisted selection.

Because Line 1 has made a substantial contribution to the genetic make-up of the Hereford breed, results from this experiment are expected to have considerable immediate application to Hereford cattle.

Effects of Different Statistical Models on Prediction of Expected Progeny Differences

M.D. MacNeil, G.B. Ferreira,
N. Gengler and L.D. VanVleck

Problem: Not all expected progeny differences (EPD) are created equal! Recent advances in computing and statistical methods open many new ways to predict EPD. Now the question is how to best evaluate candidates for selection. Today, genetic evaluation relies on statistical models that account for the heritable part of genetic differences among animals. However, mating systems may also produce variation among animals that is not accounted for. Examples include use of embryo transfer to produce large full-sib families and linebreeding. The most important source of added genetic variation is dominance. It is the form of gene action that underlies both hybrid vigor and inbreeding depression. Further, all methods to predict EPD are not equally feasible. The costs of using one method may differ from that of using another. The goal of these studies was to compare different statistical models for predicting EPD.

Procedures: These studies used data from long-term breeding experiments with Hereford cattle. Genetic evaluations were done for birth weight, weaning weight, and yearling weight. The data were analyzed with statistical models that differ from each other in how they account for sources of genetic variation. Results were summarized by changes in the ranking of individuals or sires based on EPD. Changes in estimates of heritability were also examined.

The first series of analyses were based on a "full animal model." It included direct and maternal EPD for all animals. Non-genetic similarities of the calves raised by each dam due to permanent maternal environmental effects were included. The model allowed for differences in inbreeding of calves and their dams. Finally, the base model included the correlation of direct and maternal EPD. In later analyses, this base model was reduced by leaving out one or more sources of genetic variation.

A second series of analyses used a "parent model" in which only EPD for parents were predicted directly. This model can be easier to use in large data sets because it greatly reduces the total size of the problem. Most simply only sires are evaluated and the sires are assumed unrelated. The complexity of the parent model may be increased by adding genetic relationships between sires and maternal effects.

A third series on analyses compared ways to account for dominance effects. In these analyses, the simplest model was the full animal model described above. Other analyses included different sources of dominance effects.

Findings: No major changes of heritability estimates were observed when inbreeding effects were left out of models to predict EPD. Rankings of individual animals or sires also were not affected.

Heritability estimates and the ranking of animals based on simpler versions of the animal model differed from results with the full animal model. The full animal model better separated direct and maternal genetic effects from each other and from non-genetic effects. The parent model gave similar results.

Estimates of heritability were greatest from the full animal model. They were slightly reduced using the parent model. Still lower estimates came from the parent models that included only sires or sires and maternal grand-sires. Correlations of EPD from sire models and the full animal model were also low. Thus, reranking of the animals evaluated was also important. These findings lead to the advise that sire models and sire/maternal grand-sire models should be used with caution.

Dominance effects may also exist for birth weight and weaning weight of Hereford cattle. Estimates of them changed markedly as more sources of dominance variation were added to the statistical models. Thus, when dominance effects make up part of the genetic variation, it may be important to fully include them in models used to predict EPD.

Future Directions: With increased computer power and new computing strategies, the need to test methods used in genetic evaluation continues. Data arising from long-term breeding research can be used to meet this need at very low added cost.

Relevant Publications: Ferreira, G.B. 1996. Genetic parameters for pre-weaning and growth traits estimated using different statistical models. PhD Dissertation. Department of Animal Science, University of Nebraska, Lincoln.

Gengler, N., L.D. VanVleck, M.D. MacNeil, I. Misztal, and F.A. Pariacote. 1997. Influence of dominance relationships on the estimation of dominance variance with sire-dam subclass effects. J. Animal Science (submitted).

Identification of the Gene Responsible for the Hereford AWhite-face≅ Trait

M.D. Grosz

Problem: Hereford cattle are affected disproportionately by two conditions, Bovine Ocular Squamous Cell Carcinoma (cancer eye) and sunburned udders. Both conditions have been linked to lack of pigmentation in and around the face (cancer eye) and on the underbelly (sunburned udders). In a study involving 1,500 cattle representing 6 different breeds 25.3% of Herefords, 17.6% of Hereford crosses, and <1% of 140 Holsteins showed evidence of early dysplastic lesions and/or cancer eye. Sunburned udders (which occur primarily in regions with late spring snows and early calving seasons) affect the ability of the calf to obtain milk from the mother, leading to malnourishment and, if left unchecked, death of the calf.

In addition to issues of animal health, an additional interest in coat color variation has arisen recently in the form of price discrimination at the sale barn for specific coat color patterns, in some cases regardless of the actual pedigree of the animal. Animals can sell at discounts or premiums to cohorts of similar ancestry simply because of coat color variations. Although such discounts or premiums may be temporary, one cannot dispute the effect of such economic selection on the breeding decisions made by the cattle rancher.

Procedures: Preliminary experiments were designed to identify the mode of inheritance and chromosomal location(s) of the gene(s) responsible for lack of pigmentation common to Hereford animals. Two cross-bred bulls were produced by mating Line 1 Hereford bulls to CGC (Composite Gene Combination; 2 Red Angus,3 Tarentaise, 3 Charolais) cows. These cross-bred bulls were then mated (by AI and natural service) to approximately 100 Line 1 Hereford and 100 CGC cows in two successive years to produce approximately 300 backcross calves (of either : Hereford, 3 CGC or : CGC, 3 Hereford ancestry). In the first replicate, animals were scored as either non-white or white-faced based on visual observation. In the second replicate, those animals with white faces were segregated into two groups: those which represented the Hereford phenotype and those which represented the Abaldie≅ phenotype (limited areas of non-pigmentation).

Blood was drawn from each of the calves, as well as the founder animals, and DNA was extracted. Samples were genotyped for evenly spaced microsatellite markers to identify genomic regions showing linkage with the phenotypic observations.

Findings: From the first replicate of backcrosses, it was determined that white-face is a single gene, co-dominant trait. This means that the white face phenotype is controlled by one gene. Also, animals with 2 copies of the Hereford allele appear as Herefords. Animals with 0 copies of the Hereford allele appear as non-white faced animals. But animals with 1 copy (such as Hereford crosses, or baldies) have limited areas of non-pigmentation). Experiments are currently underway to determine if baldies can be reliably segregated from Herefords on the basis of observation alone.

Microsatellite marker analysis indicated the presence of genetic linkage between markers on bovine chromosome 6 and the white face phenotype. The degree of linkage observed is sufficient to identify that region of chromosome 6 as the location of the gene controlling white face.

Once a suitable chromosomal interval was identified as the region containing the gene responsible for the trait, additional markers, including novel genetic polymorphisms identified in the lab at Fort Keogh are being used in an effort to narrow the region.

Several genes have been identified as Acandidate≅ genes for causing the white face phenotype characteristic to Hereford cattle. In an effort to identify the mutation responsible for this trait, large tracts of DNA are being screened for genetic differences between Hereford and other, non-whitefaced animals.

Future Direction: In the near future, we expect to identify the DNA mutation which is responsible for the white-faced trait. This discovery will lead to the identification of a genetic assay which can be used for Amarker-assisted selection,≅ a process through which offspring of carrier animals can be selected on the basis of the allele inherited from the carrier. Also, animals which harbor other white spotting mutations (such as Holstein, Pinzgauer, Simmental, and Galloway) will be screened to determine if the gene responsible for Hereford coat color may contain other mutations which cause different white spotting patterns in other breeds.

Relevant Publications: Grosz, M.D. 1999. A single nucleotide polymorphism in the bovine kit oncogene (Hardy-Zuckerman 4 feline sarcoma viral (v-kit) oncogene homolog). Animal Genetics (in press)

Grosz, M.D. (Bylined by Clint Peck). 1998. How will molecular DNA markers affect the cattle industry? Montana Farmer-Stockman. Mid-March. p. WB8-WB11. 1998.

Grosz, M.D. and MacNeil, M.D. 1999. The spotted locus maps to bovine chromosome 6 in Hereford-cross population. J. Heredity 90:233-236.

Grosz, M.D. 1998. AMarker assisted selection≅ made easy. Proc. International Beef Symposium. Lethbridge, Alberta, Canada., Jan. 6-8, Pp. 1-4. 1998.

Grosz, M.D. and Fahrenkrug, S. Linkage of the bovine s locus with markers in and around the kit oncogene (Hardy-Zuckerman 4 feline sarcoma viral (v-kit) oncogene homolog). (in preparation).

"Comparative Genomics" or How to Find Genes Controlling Economic Traits

E. Antoniou and M.D. Grosz

Nota Bene:
This article uses genetic concepts and terminology described in AMarker Assisted Selection made easy.≅ Thus the reader is expected to either read that article first or to already have a basic knowledge of genetics.

Limitations of Marker Assisted Selection: The article AMarker Assisted Selection made easy≅ explains how genetic markers are used to identify alleles which improve the merit of an animal. These markers can then be used to produce better animals by selecting for the favorable allele. However, a marker is usually not in the gene responsible for the favorable trait. A marker is only very close to the gene of interest on a chromosome. From this fact derives a limitation of Marker Assisted Selection (MAS). At each generation, there is a chance of recombination between the marker and the favorable allele. The farther away they are on the chromosome, the higher the recombination odds are. When this event occurs in the cell, the marker becomes associated (present on the same chromosome) with another allele of the gene, this allele coming from the second homologous chromosome in the cell. Thus, the marker becomes associated with an allele that is no longer the favorable allele we want to select for. However, there is no way to know when a recombination event occurs. Therefore, we will continue to select for this marker but we will unknowingly select for an unfavorable allele. The selection will then be ineffective and will not improve the animals.

One way to limit this risk is to identify the mutation which is causing the phenotypic difference we are hoping to select for.

The Ultimate Goal, Cloning the Genes: When the DNA mutation causing the favorable allele is known, a test can be developed that characterizes this allele versus all other alleles of the gene that do not have the desired effect on the trait. The favorable allele becomes the marker. Thus, no recombination event is possible and the MAS will always select the favorable allele.

An additional advantage of knowing which DNA mutation is responsible for the favorable allele is that this information can be used in any breed since all breeds contain the same genes (but not always the same alleles). If the favorable allele is present in the breed, it can be selected for directly. If it is not present, a selection experiment can be designed that will introduce the favorable allele in the breed. In this case, the use of MAS will dramatically increase the speed at which Abreeding up≅ can be done.

Finally, since livestock species share many genes in common, it might be possible to use information developed on a bovine gene in, for example, sheep, goat, or bison. In other words, if the gene is known, it should become possible to select for the same trait in different livestock species using information developed in only one of these species.

The Difficulties of Finding the Favorable Allele: The difficulty resides in finding the mutation responsible for the favorable allele. It is a two-step process.

The gene influencing the economic trait must first be identified. Then the allele of this gene that produces the desired effect must be characterized. The rest of this article will focus on the first part of the problem, how to find the gene.

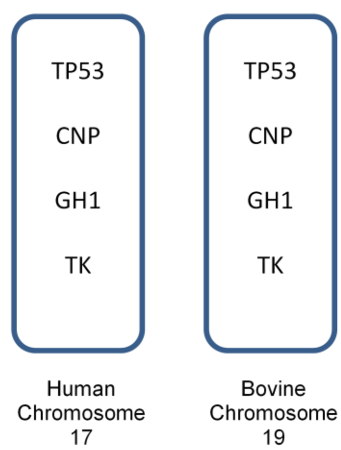
There might be as many as 100,000 genes in a typical mammal. Finding a specific gene in this pool is a daunting challenge. We can, how-ever, use what we know about the markers close to the gene as a starting point. These markers are first mapped to a chromosome (there are 30 pairs of chromosomes in cattle). Then, the positions of these markers are refined onto this chromosome. After analyzing the inheritance of a particular trait, we end up with an interval on the chromosome defined by a pair of markers. This interval is the most probable location of the gene we are looking for.

Unfortunately, due to the limitations of the Economic Trait Loci mapping experiments (number of animals, number of years the study can go on, budget limitations), this interval is likely to measure from 5 to 15 centimorgans (which means the markers will recombine 5 to 15% of the time). This interval is likely to contain anywhere from a few tens to a few hundred genes. An additional difficulty is that we do not know *a priori* how many genes are in an interval or what these genes are.

There are methods that can be used to find out which genes are present but they are, for the most part, time consuming, expensive to perform, and not very efficient.

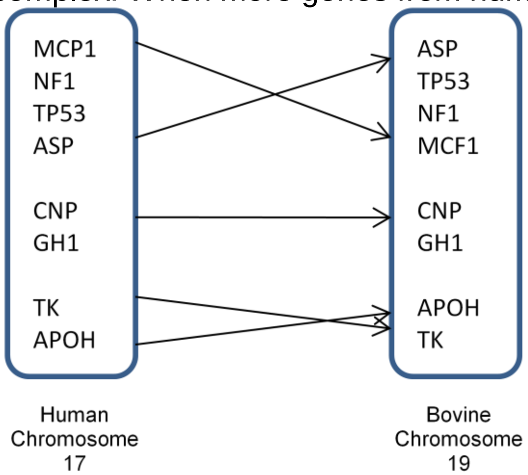
At this point, a method is needed to 1) identify genes present in the interval, and 2) sort through hundred of genes and find the one responsible for the favorable trait. This methodology is called COM-PARATIVE GENOME MAPPING or COMPARATIVE GENOMICS.

Comparative Genomics: Definition and Examples: The genomes of human, mouse, swine, bovine, sheep and goat are roughly the same size, about three billion base pairs. This DNA is assembled in chromosomes and each species has a specific set of chromosomes. However, even if the number and size of the chromosomes vary from species to species, the genes present are very similar. These genes tend to exist in **clusters**. A cluster is a set of genes that will be together on a chromosome in any of the species cited. This means that these genes will be physically close to each other on the chromosome, but the cluster can be located on different chromosomes in different species. For example, the casein gene cluster is composed of three genes coding for proteins (alpha S1/S2 and Kappa casein) found in milk. This cluster maps to bovine chromosome 23, human chromosome 6, and mouse chromosome 17. When enough genes are mapped to chromosomes in two different species, it becomes possible to



compare the species by looking where the genes map. These gene clusters are called **segment of conserved synteny**. The following picture displays an example of this concept. It shows that the genes present on human chromosome 17 all map to bovine chromosome 19.

However, the situation is usually more complex. When more genes from human



chromosome 17 are mapped onto bovine chromosome 19, it becomes evident that, even if the same genes are present on both chromosomes, the gene order is different. Three chromosomal regions can be defined where not only the same genes are present but the gene order is also the same in the two species.

The situation is often even more complex because most of the time, genes present on one human chromosome map to two or more bovine chromosomes. In other words, clusters of gene present on a bovine chromosome are found on more than one human chromosome.

In theory, it is possible to divide the bovine and human chromosomes into a finite number of segments of conserved synteny if enough genes are mapped.

Comparative genomics is the scientific field that aims to identify the segments of conserved synteny between two species.

Comparative Genomics: Its Use for the Characterization of Genes Controlling Economic Trait Loci: There are 30,000 genes mapped on human chromosomes and more are added to the map every day (the number of human genes mapped has doubled in the last 18 months). If we know all the segments of conserved synteny between human and bovine chromosomes, we then can map the 30,000 genes onto bovine chromosomes WITHOUT DOING ANY EXPERIMENTS. This will be possible because all the genes present in a segment of conserved synteny on a human chromosome will also be present in the same segment (but probably on another chromosome) in bovine. In other words, comparative genomics can allow us to use the data collected in well characterized species like mouse or human and apply it to livestock without having to do any lab experiments.

Once the genes within a segment of conserved synteny are known, **candidate genes** can be selected. A candidate gene is a gene that codes for a protein whose function is likely to affect the economic trait studied. For example, the gene coding for the growth hormone Ainsulin-like growth hormone 1" is a good candidate for traits like rib eye area or yearling weight, BUT ONLY IF the gene is located in a region that was shown to contain a gene influencing these traits. In other words, the candidate gene approach uses the localization of an economic trait loci AND gene function together to identify genes likely to affect the trait.

Conclusion: We started with about 100,000 genes and by using comparative genomics, we are now down to hopefully less than ten genes likely to control some of the genetic variation of the economic trait we want to select for. The final step will be to use *in vitro* and *in vivo* gene function characterization techniques to sort through these candidate genes.

Comparative genomics, despite being classified as basic research, is clearly an essential tool needed to make gene-based selection schemes available to the agricultural community.

Research in Comparative Genomics at Fort Keogh: A major problem right now is that not all segments of synteny conservation are known. There is a major effort needed to create comparative gene maps of sufficient detail that it will be possible to identify candidate genes.

Fort Keogh started a program two years ago that focuses on constructing a comparative gene map of bovine chromosome 25. At that time, this chromosome was poorly characterized and the mapping of genes and markers would lay the groundwork needed to find important genes. Eighteen markers are now mapped and the relationships between this chromosome and human and mouse chromosomes are known in much greater detail.

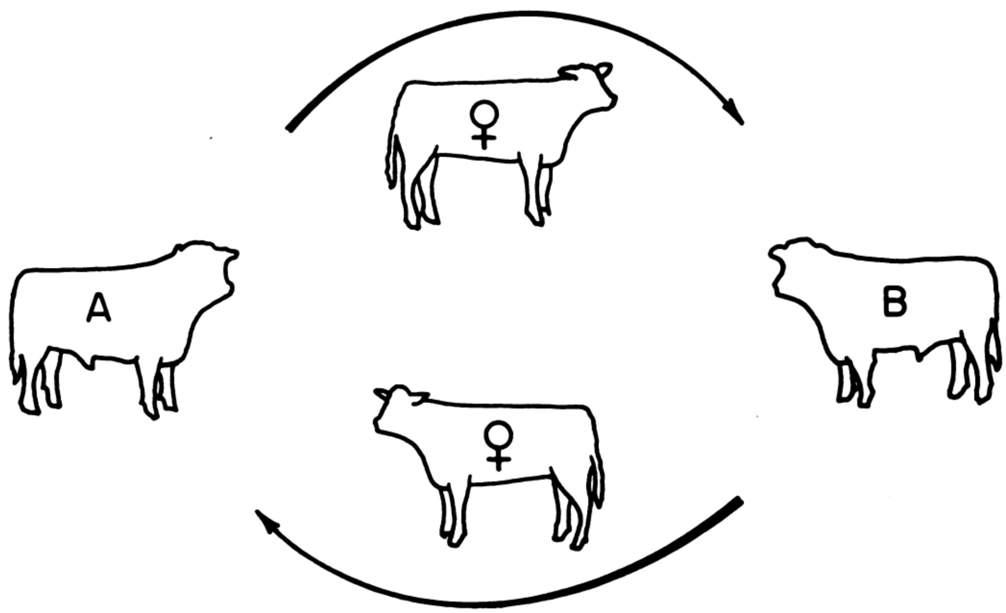
As this work is nearing completion, the program will shift to construction of comparative maps of bovine chromosomes for which the Fort Keogh ETL mapping study has already located Economic Trait Loci (see the article ΑMarker Assisted Selection made easy≅). These maps will make possible the discovery of genes governing important economic traits for the beef cattle industry and for the consumers.

F. Mating Systems

Seedstock and commercial beef producers can use genetic variation that is not heritable to improve production. The improvement comes from deciding which bull is bred to which cow, that is the mating system. Crossbreeding and linebreeding are the two mating systems most commonly used by beef producers.

Crossbreeding offers the chance to increase production to a level above that of the one best breed. The object in crossbreeding is to choose breeds that offset each others weak points and mate them in ways that maximize expressed heterosis. Heterosis may also be captured in crosses of distinct lines within breeds. However, less heterosis would be expressed by crossing lines within a breed than between breeds.

Linebreeding is a tool for seedstock breeders to increase the genetic relationship of future calves to an outstanding ancestor. The increased relationship comes from building pedigree ties to that ancestor. However, inbreeding that cannot be avoided in linebreeding may unfavorably affect the performance of linebred individuals. Offspring from linebred parents are more genetically uniform. In addition, if the choice of individual linebred to was wise, then exceptional progeny may be produced. Line 1 Hereford cattle provide a useful model for studying linebreeding.



Heterosis and Inbreeding Depression

M.D. MacNeil, F. Pariacote and L.D. VanVleck

Problem: It has been assumed that heterosis and inbreeding depression are caused by the same genetic mechanism. That is, they are two sides of the same coin. If this is true, then wide outcrosses within breeds and forming multi-breed composites both can lead to the recovery of performance lost due to inbreeding. However, renewed inbreeding depression may also result from continuing prior mating plans within breeds or from keeping a multi-breed composite as a closed herd. The goal of this study was to test the similarity of inbreeding and heterosis effects.

Procedures: Data beginning with the formation of inbred lines in 1934 were used in this study. Five of the fourteen highest performing lines developed from the 1930's to the 1960's were used in linecrossing experiments during the 1960's and 1970's. More recently, the linecrosses were mated at random in a single population. During all this time accurate pedigrees and performance records were kept. This long-term progression of research projects using Hereford cattle created a data set that was appropriate to compare effects of inbreeding and heterosis.

Findings: Birth weight, gain from birth to weaning, and weaning weight were decreased as inbreeding of either the calf or its dam increased. Crossing the inbred lines restored performance to levels expected without inbreeding, but no more. These results support the hypothesis that inbreeding depression results from loss of heterozygosity and from the dominant/recessive form of gene action. Further, heterosis results in full recovery of losses due inbreeding depression.

These results pertain to use of linebred seedstock in commercial production. All the accumulated effects of inbreeding associated with a linebreeding program can be recovered by the commercial producer.

These results also pertain to design of multi-breed composite breeding programs. Purebred cattle from any breed are alike because the breed itself is a large mildly inbred line. This appears to be why heterosis is observed when breeds are crossed. Thus, the level of performance in the composite herd should exceed the average level of contributing purebred breeds. This higher level of performance may be maintained, as long as the composite is large enough to avoid re-inbreeding.

Future Directions: Existing data from previous studies will be used as they lend themselves to answering new questions. Using these data-sets is a more efficient means of gaining new knowledge than conducting new studies. They can also form a basis for training students and short-term studies by visiting scientists.

Relevant Publications: Pariacote, F., L.D. VanVleck, and M.D. MacNeil. 1997. Effects of inbreeding and heterozygosity on preweaning traits in a closed population of Herefords under selected mating. J. Anim. Sci. (submitted).

Genetic Conservation of Line 1 Hereford Germ Plasm

M.D. MacNeil and R.B. Staigmiller

Problem: The Line 1 Hereford is a unique inbred genetic resource. Germ plasm from Line 1 has been used world-wide with large favorable impacts on the Hereford breed. Conservation of unique genetic resources is important to meet future needs of society. The National Research Council states that deciding whether or not to conserve germ plasm should not be based on current commercial value. Sales of Line 1 seedstock, by Fort Keogh, illustrate the changing economic value through time. In the 1960's, sales of Line 1 Hereford bulls averaged from $669 to $1,417 per head. Then Hereford breeders "discovered" Line 1. During the 1970's the Line 1 Hereford bulls sold averaged from $1,644 to $13,096 per head, despite offering more than 3-fold more bulls.

In beef cattle, genetic conservation depends on breeding programs of adequate size or on freezing semen and embryos in sufficient quantities to regenerate a breeding population. The goal of his research was to identify procedures appropriate for conserving Line 1 Hereford germ plasm.

Procedures: Semen from Line 1 Hereford bulls selected for use in various experiments has been collected, starting in the 1950's. Since 1988, the protocols for quality control as specified by Certified Semen Services have been followed.

In the spring and fall of 1989, eleven mature Line 1 Hereford cows had their estrus cycles synchronized. They were then superovulated and bred with semen from Line 1 Hereford bulls. Embryos were collected non-surgically and all quality 1 and 2 embryos were frozen.

In the fall of 1991, twenty virgin long-yearling Line 1 Hereford heifers had their estrus cycles synchronized. They were then superovulated and bred by natural service with experienced Line 1 Hereford bulls. Embryos were collected non-surgically and transferred fresh.

Fifty-three transfers into crossbred recipients were made in the fall of 1991. Embryos from both the 1989 and 1991 collections were transferred.

Findings: Fifty-seven percent of bulls collected produced semen suitable for freezing. Only 16% of ejaculates collected were of sufficient quality after freezing with post-thaw motility of 15-25%.

Of 42 attempted flushes, 25 yielded quality 1 or 2 embryos suitable for transfer or freezing. One-hundred fifty six embryos and 80 unfertilized oocytes were collected. Thirty one percent of the embryos were quality 1 or 2. Of 53 transfers made, 8 resulted in establishment of a pregnancy in the recipient.

Future Directions: The less than fully successful use of frozen semen and embryos from Line 1 Hereford cattle led Fort Keogh Livestock and Range Research Laboratory to preserving Line 1 as a breeding population. Breeding plans include avoiding close matings and keeping enough cows and bulls to maintain the slow increase of inbreeding. The past practice of selecting sires for high rates of postweaning growth will continue.

Relevant Publications: Staigmiller, R.B., M.D. MacNeil, R.A. Bellows, and R.E. Short. 1992. Superovulation of beef heifers with single vs. multiple injections of Folltropin. Proc. 12th International Congress on Animal Reproduction. 1:272-274.

G. Producing Lean Beef

Production of beef is the primary means for ranchers to market grass. Choice of production system affects economic, biological, and energetic efficiencies. Efficiency and market acceptability may also be affected by differences in genetic potentials of cattle for rate and composition of gain. Small amounts of fat are needed to maintain acceptable palatability. However, most cattle produced contain nearly twice fat estimated as optimal by several researchers.

Beef production systems that decrease fat and maintain a desirable level of palatability need to be developed. Methods for altering fat production may include choice of breeds that vary in body composition, age and sex of animals at slaughter, and alterations in energy input through the density of energy in the diet or length of feeding of high energy diets. Also useful are techniques to aid in evaluation of body composition of the live animal. Ultrasound technologies continue to advance in their ability to make accurate predictions of fat and lean tissue.

Effects of Growth Potential, Growing-finishing Strategy, and Time on Feed on Performance, Composition, and Efficiency of Steers

R.E. Short, M.D. MacNeil, E.E. Grings, R.K. Heitschmidt, C.B. Williams, and G.L. Bennett

Problem: Production of beef is the primary means for ranchers to market grass. In the Northern Great Plains, beef production has evolved into primarily cow/calf operations with spring-born calves marketed shortly after weaning in the fall. However, some calves may be retained and fed on ranches (backgrounded) after weaning. Retained calves are sold during the winter or kept over and grazed on pasture as yearlings before being finished as long yearlings. Grazing yearlings (either raised or purchased) is an alternative means to market grass.

Choice of a production system effects economic, biological, and(or) energetic efficiency. Similarly, it effects sustainability relative to cultural energy inputs. Producing range forage does not require the cultural energy of producing cereal and oil grains. Efficiency and market acceptability may also be affected differences in genetic potentials of the cattle for rate and composition of gain. The goal of this experiment was to determine the effect that genotype and beef production systems have on growth, composition, and production efficiency.

Procedures: Steer calves with high genetic potential for growth (HGP) were sired by Charolais bulls with high yearling weight indexes. Line 1 Hereford bulls with average yearling weight indexes sired calves with moderate genetic potential for growth (MGP). Calves were born in April or October and castrated shortly after birth. Spring-born calves were weaned in late September. Fall-born calves were weaned in April. The experiment was repeated three consecutive years. Fall-born steers were included in only the last two years. A total of 237 steers were produced. Detailed taste panel, shear force estimates of tenderness, carcass, and body composition data were collected after slaughter.

After weaning, some spring-born steers were put directly on a finishing ration at six months of age. Others were fed a growing ration from October to May, grazed range forage from May to September, and fed a finishing ration beginning in late September at 18 months of age. Fall-born steers grazed range forage during the summer with the spring-born yearling steers. The fall-born steers were fed a finishing ration beginning in September, when they were 12 months old. Individual animal nutrient intake was estimated while on pasture. During the growing and finishing phases, steers were housed in pens of six and individually fed using an electronic gate system. Spring-born steer calves were finished for 0, 90, 180, or 270 days before slaughter. Spring-born yearling steers were finished for 0, 45, 90, and 135 days. Fall-born steer calves were slaughtered after 68, 136, or 204 days on feed. Four steers with HGP and four steers with MGP were slaughtered at each time within each year. Feed consumption was recorded for 177 steers during the finishing phase. Steaks from 190 spring-born steers were evaluated for palatability characteristics by a trained taste panel.

Findings: Steers with HGP were larger and produced more carcass protein than steers with MGP. Steers with MGP were also fatter and accumulated fat at a faster rate than steers with HGP. This effect was greater in older steers.

As time-on-feed and age at the start of the finishing period increased, the weight, fat depth, marbling, and flavor intensity also increased. However, age and time-on-feed had little or no effect on gain, intake, efficiency, tenderness, or juiciness.

Yearling-fed HGP steers were too large with insufficient fat to meet guidelines of the National Beef Quality Audit. Calf-fed MGP steers were also too small at a desirable degree of finish. Thus, high growth rate calves may be best used in a direct growing-finishing program, whereas, moderate growth rate calves may be better suited to a growing-grazing-yearling finishing program. Fall calving may be an alternative to use high growth rate potential calves in a summer grazing-backgrounding program before finishing.

Future Directions: These data are being used in cooperative studies for modeling production systems.

Relevant Publications:

Adams, D.C., R.E. Short, M.M. Borman, and M.D. MacNeil. 1991. Estimation of fecal output with an intra-ruminal continuous release a marker device. J. Range Manage. 40:204-207.

Short, R.E., E.E. Grings, J.H. Killen, G.L. Bennett, and R.K. Heitschmidt. 1993. Effects of genotype and management system on postweaning production efficiency and composition of beef. VII World Conference on Animal Production, Edmonton, Alberta, Canada 2:362-363.

Retained Ownership: a Management Strategy for Cow-calf Producers to Increase Profitability

M.D. MacNeil, L.W. Van Tassell, S.M. McNeley, R.E. Short, and E.E. Grings

Problem: Greater profit and lower risk have been familiar cries by beef industry analysts. Retained ownership of weaned calves can help producers increase their market power and reduce price risk. Producers may also reap rewards from a sound breeding program with retained ownership. The goal of this study was to identify optimal strategies for retained ownership of weaned calves considering both production and price risk.

Procedures: A computer model of beef production was developed using data from two genetic groups of steer calves. The calves were sired by Charolais bulls with high genetic potential for growth potential or by Line 1 Hereford bulls with moderate genetic potential for growth. Calves were born in April and weaned in mid-September. After weaning, some calves were put on a finishing ration at 6-months of age. Others grazed irrigated pasture during the fall, were fed a growing ration over the winter, grazed native range during the next summer, and were put on a finishing ration in late September at 18-months of age. Feed intake was measured during each production period. Calf-fed steers were slaughtered at weaning or after 90, 180, and 270 days on feed. Yearling-fed steers were slaughtered coming off grass or after 45, 90, and 135 days on feed. Average time-on-feed to reach the low-choice quality grade was predicted from the carcass data for each growth potential and management strategy.

Historical cattle and feed prices were also input for the computer model. Average prices and the variation in them were modeled for both inputs and products were all modeled. This model also included a series of marketing times, production alternatives, and pricing scenarios. Thus, 166,320 different end-points were evaluated for each steer. Six decision periods were considered: 1) Weaning calves could be sold on 15 October; 2) Weaned calves could graze irrigated pasture and then be sold on 1 January; 3) Calves that came off grass 1 January could be backgrounded to 10 May and then sold; 4) Backgrounded calves could graze native range from 10 May to 20 September and be sold as long-yearling steers; 5) Long-yearling steers could be fed from 20 September to the low-choice carcass grade and then sold; and 6) Weaned calves could be placed in a feedlot, fed low-choice carcass grade, and then sold. In this model, all cattle were sold on a live-weight basis without any price premiums or discounts based on carcass weight or yield grade.

All decision periods were evaluated for both risk-neutral and risk-adverse producers. Risk-adverse producers are more cautious than their risk-neutral counterparts. They will sacrifice some amount of expected income to reduce the chance of lower income or loss. For example, risk-adverse producers will not give up a certain income of say $40/head for a 50-50 chance of either $20/head or $60/head. A risk-neutral producer is indifferent to these alternatives. The net result of these choices is that risk-adverse producers realize lower, but less variable, income streams than risk-neutral producers.

Findings: Risk-neutral producers retained calves after weaning, using fall grazing until January 1. If potential profits were high, they tended to sell moderate growth potential steers then. However, they continued to retain ownership of high growth potential steers through to slaughter.

Risk-adverse producers sold part of the calf-crop at weaning in October. The proportion of calves sold at weaning increased with increasing profit potential. Risk-adverse producers tended to feed out more calves. They retained fewer yearlings to graze the following summer and for subsequent finishing. This selling strategy served to spread risk across several selling points and reduced variation in income. However, risk-adverse producers had lower income levels than their risk-neutral producers.

Decisions were affected by the level of potential profit at each selling point. When potential profits were low, more steers were retained through the following production periods. As potential profits increased, more steers were sold at earlier endpoints. Thus, the model conformed to optimal profit-taking behavior.

Income varied more across production years for high growth potential steers than for moderate growth potential steers. This reflects the greater sensitivity of high growth potential steers to changes in production environment, perhaps due to their greater nutritional requirements. Conversely, moderate growth potential steers buffered changes in production environments better. High growth potential steers tended to be retained longer in poor years than in good years.

As with most economic analyses, these results do not transfer directly to any one decision maker. They provide general guidance for cow-calf producers wanting to examine retained ownership. By using retained ownership they may reduce risk, capture benefits from superior seedstock, and increase profits.

Future Directions: The computer model used for this study is being refined. The present results may be improved by including price premiums and discounts based on carcass weight and yield-grade. Costs of production that are specific for differing genetic inputs would improve the comparison of genotypes. Modeling cash flow and tax consequences of retained ownership over more than one year will aid producers in assessing its impact.

Relevant Publications: McNeley, S.M. 1996. Optimal steer retention and production alternatives considering production and price risk. MS Thesis in Agricultural Economics, University of Wyoming, Laramie.

Effects of Hypermuscularity on Beef Production

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

Problem: Beef production in the United States is a billion-dollar industry that produces too much fat. Small amounts of fat are needed to maintain acceptable palatability. Because consumers demand enough fat to enhance palatability, beef is marketed in a system that pays premiums for fat. However, most cattle produced contain nearly twice the 3 to 7 percent carcass fat estimated as optimal by several researchers. This excess fat production is inefficient. Ironically, excess fat is also a major obstacle in consumer acceptance. Whether based on fact or perception, consumers are anxious about effects of eating too much saturated fat. Therefore, beef production systems that decrease fat and maintain a desirable level of palatability need to be developed.

One strategy to reduce fat production is to use muscular breeds of cattle. The increased muscling could be as extreme as in Piedmontese or Belgian Blue or more moderate as in other European breeds such as Limousin, Charolais, or Maine-Anjou. In the extreme, this trait is called hypermuscularity or double-muscling. Calves sired by these breeds may have more desirable carcass composition compared with calves sired by breeds with less extreme muscularity. Using more muscular breeds has potential for immediately improving composition without using drugs or implants.

Use of hypermuscularity or double-muscling in beef production systems is hampered because its inheritance is not fully understood. Without this knowledge, it is difficult to design breeding systems. Also unknown are the effects of hyper-muscularity on other important production traits such as reproduction. The goals of this research are to better understand genetic control of hypermuscularity and its associations with other economically important traits.

Procedures: Crossbred cows and heifers that did not have extreme muscularity were bred by AI to bulls from breeds with differing genetic potentials for muscularity. Piedmontese (P) bulls represented hypermuscularity (HM) genotypes, Limousin (L) bulls represented genotypes with more moderate muscularity (MM), and Hereford (H) bulls represented normal muscularity (NM) genotypes. About 300 F1 progeny were produced from each breed of sire over two years. Within each breed, 20 to 25 different bulls were used to insure a broad sampling of each genotype.

Effects of degree of muscularity on slaughter and carcass traits are determined using the F1 male calves. The F1 females have been bred with bulls of the same cross to produce F2 progeny for three years. Reproductive performance by these females contributes to determining effects of muscularity on reproductive traits. In the F2 progeny, segregation of genes for muscling will yield data to understand their inheritance. Degree of muscling for individual animals is being assessed by a combination of visual scores, ultrasound measurements of muscles, microscopic (histological) measurements of muscle biopsies, and carcass data.

Findings: Collection of data at calving, weaning, and slaughter data of the F1 calves has been completed. Age at puberty has also been determined for all F1 heifers. Degree of muscularity had little effect on calving or weaning data (Table 1) except th[illegible] increased with increased muscularity. Age at puberty was markedly different among the three genotypes (Table 1). The MM genotype was oldest and the HM genotype was youngest at puberty.

The carcass data (Table 2) were consistently related to muscularity. As muscularity increased, fat depth and marbling score decreased and ribeye area, dressing %, and primal cuts increased. Tenderness was also affected by genotype. Steaks from HM were most tender and steaks from MM were least tender. Gain and efficiency differed among the genotypes (Table 2) with MM growing fastest and most efficiently, followed by NM, and then HM. Use of sires with increased muscularity can increase production of lean beef while maintaining sufficient levels of traits associated with consumer preferences. The HM-sired cattle produced carcasses with up to 25% more lean and with less in fat than NM-sired cattle. Because the [illegible]eased muscularity arises from exaggerated development of muscle fibers, the connective tissue component of the meat is altered and it is more tender. If HM genotypes were used to sire slaughter progeny, consumers could obtain beef that is highly palatable and be less concerned about fat intake.

Future Directions: Evaluation of reproductive performance by the F1 females is continuing as is production of F2 progeny for genetic evaluations.

Table 1. Effects of genotype on calving, weaning, and puberty traits of F1 calves.

Genotype (Sire Breed)	Gestation Length, days	Birth Weight, lb	% calving Difficulty	Weaning Weight, lb	Heifer age at puberty, days
NM (H)	283	84.7	14.9	453	378
MM (L)	287	89.3	20.2	456	399
HM (P)	288	88.7	24.6	452	356

Table 2. Effects of genotype on carcass traits of F1 calves.

Genotype (Sire Breed)	Live Wt (lb)	Carcass Wt (lb)	Ribeye Area (in^2)	Fat depth (in)	Marbling Score	Tender-ness tests (lb)	% Primal Cuts	Gain (lb/day)	Efficiency (oz/lb)
NM (H)	1174	684	12.5	.32	11.7	7.8	53	2.8	3.3
MM (L)	1187	700	13.3	.25	10.3	8.1	54	2.9	3.6
HM (P)	1151	698	14.6	.16	9.4	7.3	55	2.6	3.2

Relevant Publications: Grings, E.E., R.E. Short, M.D. MacNeil, M.A. Lammoglia, R.B. Staigmiller, and R.A. Bellows. 1997. Postweaning production of F1 males from Hereford, Limousin, or Piedmontese sires. J. Animal Sci. (In preparation).

Comparison of Ultrasound Systems to Predict Marbling in Beef Cattle

M. D. MacNeil, W. O. Herring, L. A. Kriese, K.K. Bertrand, and J. Crouch

Problem: Marbling is an important determinant of carcass value. Using ultrasound to predict marbling in live animals may improve feed-yard management and accelerate genetic improvement. Today, there are several commercially available ultrasound systems that claim to predict marbling. Therefore, the Beef Improvement Federation Live Animal and Carcass Evaluation Committee asked that a series of studies be conducted to evaluate these systems. This study contributes to that goal.

Procedures: Cattle used in this study were Line 1 Hereford (n=48) and CGC composite (n=32) steers. Intact bulls were fed from weaning to about one year of age. The diets were based on corn silage with some added grain, primarily barley, and 10% chopped hay. At one year of age the bulls used were identified as culls due to either low performance or excessive birth weight. They were castrated using the Callicrate system. These steers then grazed native range at Miles City until August 21 when they were returned to the feedlot for finishing. Coming off pasture their average weight was 966 pounds. The finishing ration consisted of 80% well eared corn silage, 10% corn grain, and 10% barley.

Four commercially available ultrasound systems were represented in this study. These systems all estimated marbling by applying image analysis procedures to a region of interest within the rib-eye muscle. To allow the best possible representation of each system, each company was allowed to select and send two experienced technicians. The systems[1] represented were: Animal Ultrasound Services Inc., Ithaca, NY; CPEC, Oakley, KS; Critical Vision Inc., Atlanta, GA; and Classic Ultrasound Equipment, Tequesta, FL. The CPEC systems predicted marbling score directly. The other systems predicted percent fat within the muscle which was converted to marbling score. These evaluations reflect the state of technological development as of October, 1996. Later changes to these systems may alter their performance.

Animals were scanned over 3 days. Cattle were sent to slaughter in four groups of 20 head each, beginning the day after scanning and every 7 days thereafter. Marbling was determined 36 to 48 hours after slaughter by an experienced grader. After grading a slice of the rib-eye muscle was taken to determine percent fat within it. The correlation between marbling score and percent fat was 0.74.

Several statistics were used to evaluate the proficiency of each system. Rank correlations assist in determining similarity of the ranking of two variables. In this case, they were marbling predicted using ultrasound and marbling scored by the grader. Accuracy assists in determining the similarity of predicted marbling and its direct observation. Bias indicates the magnitude and direction error.

Findings: The carcass data recorded in the cooler are presented in Table 1.

These cattle were fed for less than 90 days and castrated at a year of age. Thus, the fat and muscle traits may be more similar to those of bulls than of steers.

Table 1. Description of live and carcass data

Trait	Minimum	Mean	Maximum
Live wt., lbs.	1014	1166	1333
Carc. wt., lbs.	565	656	752
Fat depth, in.	0.05	0.24	0.60
Ribeye, $in.^2$	9.3	12.1	15.9
Marbling[a]	3.4	4.5	6.1

[a] 3=traces, 4=slight, 5=small, 6=modest

Presented in Table 2 are descriptive statistics relating ultrasonic predictions of marbling, by system to the observations. The CPEC and Critical Vision systems had the higher correlations with measured marbling and greater accuracy and less bias in its prediction than did Animal Ultrasound Services and Classic Ultrasound Equipment systems.

Table 2.

System[a]	Correlation	Accuracy	Bias
CPEC	0.54	0.57	-0.09
CVIS	0.47	0.64	-0.13
AUS	0.03	2.12	0.95
PIE	-0.04	1.75	-1.06

[a] CVIS=Critical Vision; AUS=Animal Ultrasound Services and PIE=Classic Ultrasound Equipment.

Results from these data agree with earlier studies evaluating these technologies. It is feasible to use ultrasound for predicting marbling. However, not all commercially available systems are equivalent. Thus, before using ultrasonic predictions of marbling in decision making the utility of the particular system should be established.

Future Directions: Collaborative studies in service to the cattle industry are central to the mission of Fort Keogh Livestock and Range Research Laboratory. As opportunities to provide this service arise they will be pursued with vigor.

Relevent Publications: Herring, W.O., M.D. MacNeil, L.A. Krise, J.K. Bertrand, and J. Crouch. 1997. Comparison of four real-time ultrasound systems that predict intramuscular fat in beef cattle. Proc. Beef Improvement Federation, Dickenson, ND. (in press).

Dietary Protein Level and Source for Postweaning Production of F1 Cattle from Hereford, Limousin, or Piedmontese Sires

*E.E. Grings, R.E. Short,
and M.D. MacNeil*

Problem: Increased production of lean meat may be achieved by use of cattle breeds that express various degrees of muscle hypertrophy. This trait can dramatically increase muscle size and decrease carcass fat. Increased muscle mass could influence protein requirements.

The protein requirement of purebred Belgian Blue bulls was shown to be greater than that of other cattle, while other research has found no breed x dietary protein level interactions on growth or carcass characteristics for Belgian Blue x Holstein and Holstein steers. Several studies in cattle without muscular hypertrophy have shown increased fat deposition with increased dietary protein.

One objective of this study was to evaluate the dietary crude protein level on growth and carcass characteristics of male cattle that vary in degree of muscularity.

Table 1. Ingredient and chemical composition of diets fed to steers and bulls during the growing and finishing phases. Diets varied in crude protein (CP) in Year 1 and in undegradable intake protein (UIP) in year 2.

	Year 1				Year 2			
	Growing diet		Finishing diet		Growing diet		Finishing diet	
Item	Low CP	High CP	Low CP	High CP	Low UIP	High UIP	Low UIP	High UIP
Ingredient	%DM							
Corn silage	54.3	54.3	44.7	44.7	49.7	49.7	42.8	42.8
Rolled barley	33.4	30.7	54.0	51.5	30.9	28.8	56.1	55.6
Chopped alfalfa hay	10.4	10.4	-	-	14.1	14.1	-	-
Blood meal	-	1.9	-	-	-	2.9	-	.7
Corn gluten meal	.4	1.4	-	2.6	-	-	-	-
Soybean meal	-	-	-	-	3.8	3.8	-	-
Urea	.2	-	.1	-	.8	-	.2	-
Salt	.6	.6	.5	.5	.2	.2	.2	.2
Dicalcium phosphate	.4	.4	.1	.1	-	-	-	-
Limestone	.2	.2	.5	.5	.4	.4	.6	.6
Trace mineral mix	.1	.1	.1	.1	.1	.1	.1	.1
Chemical composition								
DM	47.4	48.1	51.2	51.2	44.5	41.3	46.3	46.7
CP	10.2	12.1	9.5	10.1	12.8	13.4	11.8	11.5
Estimated DIP	7.6	7.7	6.9	6.9	9.8	8.8	8.7	8.0
Estimated UIP	2.6	4.4	2.6	3.2	3.0	4.9	3.1	3.5
NDF	40.5	39.5	37.9	37.9	-	-	-	-
ADF	20.1	19.6	18.0	17.9	17.2	21.5	14.8	15.5

Table 2. Effects of dietary protein treatment within years on growth and ultrasound compositional measurements during the growing period (weaning to 853 lb) for male cattle.

	Year 1		Year 2	
Variable	High protein	Low protein	SBM	BM
ADG, lb/d	2.97	2.44	2.95	3.11
TDN efficiency lb weight gain /lb TDN	.29	.26	.29	.31
Days to reach 850 lb	119	143	99	99
Longissimus muscle area at 850 lb, in^2	10.5	10.2	10.4	10.9
Backfat thickness at 850 lb, in	.055	.11	.26	.13

Table 3. Nitrogen (N) retention and dry matter (DM) and neutral detergent fiber (NDF) digestibility of bulls of 3 sire breeds fed 2 diets with high or low CP.

	Hereford		Limousin		Piedmontese	
Item	High CP	Low CP	High CP	Low CP	High CP	Low CP
DM intake						
lb/d	10.4	9.9	9.3	8.4	9.5	8.6
lb/100 lb BW	1.62	1.61	1.42	1.30	1.46	1.39
Apparent DM digestion						
lb/d	7.0	6.4	6.4	5.5	6.2	5.5
% of intake	67.7	64.1	69.1	65.5	66.5	65.6
N intake						
lb/d	.24	.19	.20	.17	.22	.18
N disappearance						
lb/d	.16	.11	.13	.10	.14	.11
% of intake	65.8	57.0	64.5	60.4	64.8	60.0
N excreted						
lb/d	.08	.07	.09	.07	.07	.07
N retention						
lb/d	33	19	20	15	33	18
% of intake	29.4	20.1	21.8	18.1	31.6	23.0
NDF digestion						
lb/d	1.6	1.4	1.4	1.2	1.3	1.3
% of intake	45.0	39.3	45.5	42.1	42.1	44.1

Procedures: Crossbred cows were bred by artificial insemination (AI) for 2 years to normal muscled Line 1 Hereford sires, moderate muscled Limousin sires, or hypermuscular Piedmontese sires. Sire breeds were chosen for their potential differences in muscling but similarities in size and growth rate. Male calves were randomly assigned within sire to be castrated or left intact at approximately 2 months of age. Calves remained with their dams until approximately 7 months of age. After weaning, 131 male calves were placed into covered pens having individual electronic feeding gates with 6 animals housed per pen. Bulls and steers were housed in separate pens.

Calves were individually fed growing diets from weaning to 850 pounds and were then switched to finishing diets for 90 or 132 days. Cattle were on either high or low protein (year 1) or highly or lowly degradable protein (year 2) throughout both the growing and finishing periods (Table 1). Due to lower than expected crude protein concentrations of alfalfa hay and corn silage in year 1, dietary crude protein was lower than expected. Low levels of dietary protein could limit response to dietary differences.

Ribeye area and backfat thickness were determined by ultrasound scanning within 10 days of reaching 850 pounds to determine the effect of growing diet on these characteristics.

Cattle were slaughtered at a commercial abattoir using standard industry procedures. Hot carcass weight was taken during the day of slaughter and other carcass measures were taken after 48 hours of storage at 2^{o}C.

Nitrogen Retention Study

In year 1, 36 bulls were used to evaluate the effect of sire breed on nitrogen retention during the growing phase. Twelve bulls of each sire breed were allotted to one of 2 diets. Diets were similar to the growing diet for year 1 shown in Table 1, with the exception that there was no urea in the low crude protein diet and both diets contained .7 ounces monensin per ton of diet on an as fed basis. Dietary protein during the metabolism trial averaged 11.2 and 12.9% for the low and high protein diets, respectively. The protein values differ from the average fed during the feedlot study because of the shorter period of time over which diets were fed. Bulls were housed in two unshedded lots with one diet fed in each pen. Bulls were assigned by weight to a period in metabolism crates with a maximum of 8 bulls per period. At approximately 640 pounds, bulls were placed into metabolism crates for total collection of feces and urine. Bulls had previously been trained to stand when tied with a halter. Bulls underwent a 5-day adaptation period followed by 5-day of total collection. Bulls were fed once daily and feed intake was adjusted to 95% of ad libitum consumption.

Findings:

Feedlot Study

The high protein diet fed in year 1 had similar degradable protein levels but higher undegradable protein levels than the low protein diet. In year 2, the two diets were similar in protein level, but a greater proportion of protein in the blood meal diet was undegradable protein compared with the soybean meal diet.

In year 1, cattle fed the higher protein diet gained faster than cattle on the lower protein diet. This resulted in a decreased number of days to reach 850 pounds and also an improvement in feed efficiency. In year 2, cattle fed the blood meal diet gained faster and had better feed efficiencies than cattle fed the soybean-meal urea diet. These results are consistent with one another, indicating that a higher level of undegradable protein in the diet improved weight gain during the growing period.

There was no effect of dietary protein level on weight gains during the finishing phase or on carcass characteristics. This is not unexpected as both total protein and undegradable protein needs decrease as weight gain shifts from lean tissue growth to fat tissue growth throughout the finishing period.

Nitrogen Retention Study

Sire breed did not affect nitrogen retention in bulls fed corn silage-barley-based diets of either 11.2 or 12.9% crude protein. Diet did affect nitrogen retention due to both an increased intake and an increase in the percentage of dietary nitrogen disappearing in the digestive tract for bulls fed the higher nitrogen diet. This is consistent with the increased rate of gain and improved feed efficiency observed in the cattle fed the higher protein diet during the growing phase of the feedlot study.

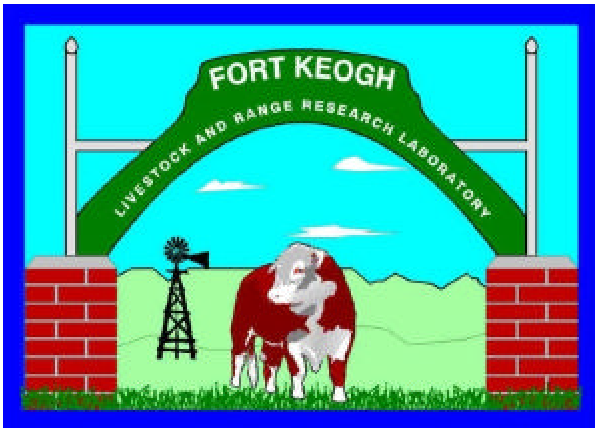
Future Direction: This phase of the hypermuscularity study was completed as we began to evaluate the F2 calves produced in the project.

Relevant Publications:

Grings, E.E., R.E. Short, M.D. MacNeil, and B.L. Balsam. 1996. Effect of sire breed, gender, protein, and length of finishing on growth and carcass composition of beef cattle. Proc. West. Sec. Amer. Soc. Anim. Sci. 47:235-238.

USDA-ARS-Fort Keogh
Staff Directory
Livestock and Range Research Laboratory
Rt. 1 Box 2021
Miles City, MT 59301

Name	Title	Phone Number	E-Mail Address
Antoniou, Eric	Post Doc Genetics	406-232-8225	eric@larrl.ars.usda.gov
Armstrong, Doug	Farm/Ranch Hand	406-232-8210	
Arnoldt, A. Butch	Farm/Ranch Hand	406-232-8220	
Arnoldt, Eddie	Equipment Mechanic	406-232-8210	
Austill, Diona	RL Secretary	406-232-4970	diona@larrl.ars.usda.gov
Bellows, Norm	Res. Associate Nutrition	406-232-8208	
Bellows, Robert A.	Physiologist	406-232-8216	bob@larrl.ars.usda.gov
Bellows, Sue	Bio. Lab. Tech. Phys.	406-232-8204	sbellows@larrl.ars.usda.gov
Bryan, Benny	Farm/Ranch Hand	406-232-8220	
Bundy, Duane	Farm Agric. Res. Tech.	406-232-8218	
Clendenen, Janice	Administrative Clerk	406-232-8219	janice@larrl.ars.usda.gov
French, Larry	Bio. Lab. Tech. Gen.	406-232-8221	larry@larrl.ars.usda.gov
French, Mary Ellen	Automated Office Asst.	406-232-8224	mefrench@larrl.ars.usda.gov
Geary, Tom	Physiologist	406-232-8215	tgeary@larrl.ars.usda.gov
Gilbertson, Nancy	Purchasing Agent	406-232-8214	nancy@larrl.ars.usda.gov
Gresens, JoAnne	Safety Officer	406-232-8230	joanne@larrl.ars.usda.gov
Grings, Elaine E.	Nutritionist	406-232-8202	elaine@larrl.ars.usda.gov
Grosz, Michael D.	Molecular Geneticist	406-232-8206	grosz@larrl.ars.usda.gov
Haferkamp, Marshall	Rangeland Scientist	406-232-8211	marshall@larrl.ars.usda.gov
Harris, Rick	Farm/Ranch Hand	406-232-8229	
Hendry, Lee	Maintenance Worker	406-232-8210	
Heitschmidt, Rod	Rangeland Ecologist	406-232-4970	rod@larrl.ars.usda.gov
Hilderbrand, Ralph	Maintenance Sup.	406-232-8210	
Hould, Byron	Asst. to the Supt.	406-232-8226	byron@larrl.ars.usdagov
Howard, Jim	Farm/Ranch Hand	406-232-8220	
Kessler, Jim	Farm/Ranch Hand	406-232-8238	
Klement, Keith	Range Technician	406-232-8232	keith@larrl.ars.usda.gov
Lockie, Sandi	State Admin. Asst.	406-232-8201	sandi@larrl.ars.usda.gov
MacNeil, Michael D.	Geneticist	406-232-8213	mike@larrl.ars.usda.gov
Mott, Tom	Agr. Res. Spec.	406-232-8238	
Murphy, Cheryl	Bio. Lab. Tech. Range	406-232-8231	cheryl@larrl.ars.usda.gov
Phelps, Dave	Res. Associate - Phys.	406-232-8229	
Reil, Sue	Bio. Lab. Tech. Nutrition	406-232-8203	sreil@larrl.ars.usda.gov
Scheeler, Ralph	Heavy Equip. Operator	406-232-8210	
Schied, Lynn	Farm/Ranch Hand	406-232-8220	
Shipp, Brooke	Bio. Lab. Tech. LB	406-232-8205	brooke@larrl.ars.usda.gov
Short, Robert E.	Physiologist	406-232-8235	bshort@larrl.ars.usda.gov
Speelmon, Mish	Agr. Res. Spec.	406-232-8236	mish@larrl.ars.usda.gov
Strobel, Ken	Equipment Mechanic	406-232-8210	
Taylor, Cody	Farm/Ranch Hand	406-232-8238	
Watts, Jim	Farm/Ranch Hand	406-232-8238	
Woods, Mike	Farm/Ranch Hand	406-232-8229	



FORT KEOGH LIVESTOCK AND RANGE RESEARCH LABORATORY_

Home of Line 1 Herefords, Rod and the Bobs and Mikes, and lots of exciting range and beef cattle research.

Fort Keogh's Mission

To research and develop ecologically and economically sustainable range animal management systems that ultimately meet consumers needs.__

Discover our: **RESEARCH PUBLICATIONS HISTORY PEOPLE EVENTS**

Visit affiliated sites:

ARS Homepage
Northern Great Plains Area Office Homepage
Search ARS

Ag Experiment Station
Extension Service
Department of Animal and Range Sciences

Let us know what you think. We welcome feedback as we try to keep you up-to-date on research activities at the Fort. Send comments about our web site to web@larrl.ars.usda.gov. General questions and comments about Fort Keogh may be directed to staff@larrl.ars.usda.gov. Specific questions and comments pertaining to our research may be sent to individual scientists, or you can try scientists@larrl.ars.usda.gov and we will try to respond as time permits.

USDA-ARS Fort Keogh LARRL
Route 1 Box 2021
Miles City, MT 59301
Phone: (406)232-4970
Fax: (406)232-8209