Fort Keogh
Livestock and Range
Research Laboratory

2003 Research Report

USDA-Agricultural Research Service
In cooperation with the
Montana Agricultural Experiment Stations

United States Department of Agriculture
Agricultural Research Service
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Edited by E.E. Grings.

Front page drawing of how the new building will look was provided by Jacobs Architectural Firm.

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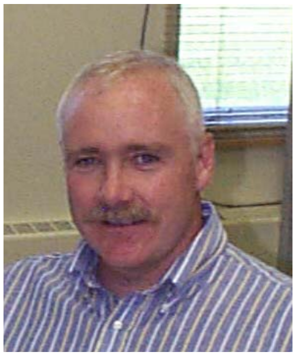

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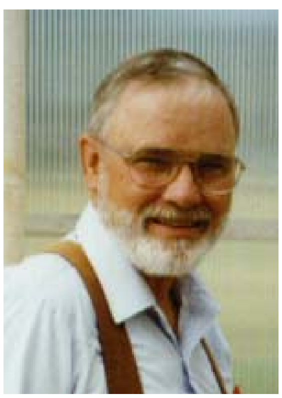

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2002

PRODUCER RECOGNITION AWARD

Keith Bales

Otter, Montana

Biography

Keith Bales, recipient of the 2002 Fort Keogh Producer Recognition Award, was born on 15 March 1944 to Walter B. and Margaret Bales. He was raised on the family ranch near Otter, MT. He and his wife of 28 years Christl have two children, Brian (25) and Michael (23).

After high school he attended Montana State University, Bozeman from 1962-1967 and received a B.S. in Agricultural Production, Animal Science.

He served in the U.S. Army from 1968-1970 attaining the rank of Lieutenant.

Keith has served as Vice President and on the Board of Directors of the Tongue River Electric Cooperative from 1982 to present.

He has worked with the family's Bales Ranch Inc. from 1970 to present and has been President/Manager since 1994. The Bales Ranch Inc. is a commercial cow/calf/yearling 1,000 animal unit operation located in southeastern Montana in Powder River County They also produce hay, grain, and alfalfa seed.

Keith has been very actively involved in agriculture on and off the ranch. He served as President of the Southeastern Montana Stock Grower's Association from 1985-1987; served the Montana Stock Grower's Association as a Director from 1989-1993, Vice President from 1994-1998, and President from 1998-2000; and served the National Cattlemen's Beef Association as a Director from 1992-2001, as Vice Chairman for the Federal Lands Committee in 1992, as a member of the Country of Origin Task Force in 1997, and as a member of the Price Reporting Task Force in 1998.

Most recently, Keith was elected to the Montana House of Representatives in 2000 and serves on the Taxation, Natural Resources, and Fish, Wildlife, and Parks Committees.

Keith has been a supporter of research efforts at Fort Keogh for many years and has served on the Customer Focus Group since 1994.

Keith Bales has also been an outstanding supporter of MSU extension programs and programs to assist Montana beef producers. As the president of Montana Stockgrowers, he was a driving force in the establishment of the Montana Beef Network (MBN) which was initiated in an attempt to increase the value of Montana feeder calves. The objectives of the MBN are to provide Beef Quality Assurance training, feeder calf certification, and data return from the feedlot and packing plant. This program was established as a joint effort between MSU and MSGA. The program is starting to show positive results with MBN producers receiving more money for their calves than non-MBN members.

In addition, Keith was a research cooperator for a project which was aimed at reducing morbidity and mortality of weaned calves. Twelve ranches participated in this two-year project. Morbidities were reduced by 50% and death loss by 33% when producers followed the MBN protocol of weaning versus traditional methods.

It is for his active involvement in agriculture and supporting research at Fort Keogh that we want to recognize Keith Bales with the Producer Recognition Award for 2002.

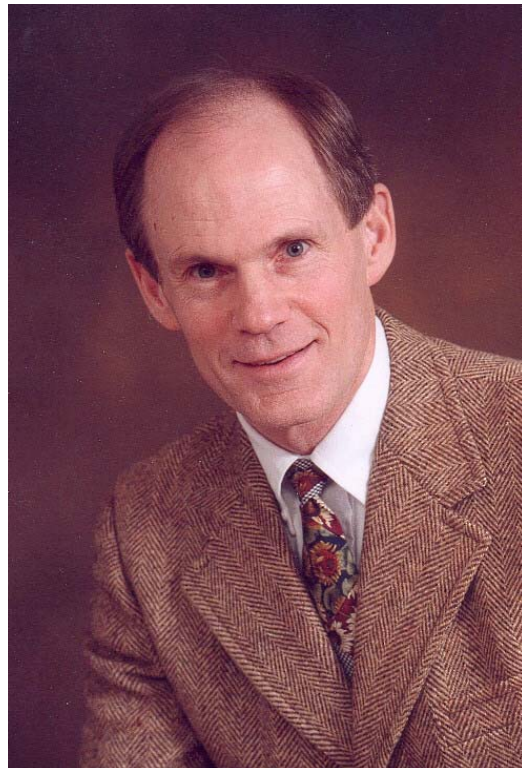
2002

PRODUCER RECOGNITION AWARD

John Munsell

Miles City, Montana

Biography



John Munsell, recipient of the 2002 Fort Keogh Producer Recognition Award, was born on 5 August 1946 in Miles City, MT, the fourth of ten children to Wes and Agnes Munsell. He and his wife, Kathryn, of 34 years have two children, Julie Christine and Ann Marie. He is the proud grandfather of two grandchildren (ages 4 years and 11 months).

After high school, John attended Carroll College in Helena, MT; Crosier Seminary in Onamia, MN; and Montana State University, Bozeman, MT. He graduated from MSU in 1968 and received a B.S. in Agricultural Business with a minor in Economics.

He served in the Army Reserve and National Guard from 1970 to 1976 in Butte and Miles City, MT.

Early in his career, he worked for Continental Oil Co. in Ponca City, OK, and Target Stores in Minneapolis, MN.

Locally, John is involved with many organizations and activities including Miles City Jaycees, Knights of Columbus, Miles City Chamber of Commerce, RSVP, Library Board, Range Riders Museum, and Custer County Art Center.

John's agricultural related activities are many, beginning with active involvement with Scouts and working on the family ranch during summers. From 1971 to present, he has been manager of Montana Quality Foods and Processing, formerly known as Miles City Packing Plant. He is a member of the American Association of Meat Processors (1982-present); charter member and Legislative Director for Montana Meat Processors Association (1987-present); and a member of the National Meat Association.

John Munsell and Montana Quality Foods and Processing are highly valued partners in the research conducted by scientists at Fort Keogh Livestock and Range Research Laboratory. It is through this partnership that we can determine the ramification of our research to the beef that is ultimately produced. John has been extremely gracious in allowing us access to all areas of the Montana Quality Foods and Processing plant facilitating collection of reproductive tracts and other organs, collection of carcass data, grinding samples to determine body composition, and harvesting meat for further sensory evaluation. Specific examples of research that depend upon our partnership include: exploring opportunities to enhance production of lean beef; assessing consequences of genetic selection strategies; identification of quantitative trait loci affecting carcass quality, yield, and palatability; and collection of tissue samples to evaluate reproductive processes.

It is for his active involvement in agriculture and supporting research at Fort Keogh that we want to recognize John W. Munsell with the Producer Recognition Award for 2002.

A. Rangeland Productivity

Grasslands, shrublands, savannas, tundra, and forests that support grazing comprise nearly 40% of the world's land surface and are collectively called rangelands. Rangelands are generally diverse communities of native plants that are managed as natural ecosystems. The Northern Great Plains include about 150 million acres of rangeland that are primarily utilized for livestock production, wildlife, and outdoor recreation.

Management of rangelands is often complicated by the complex mixtures of species and soils and by weather conditions that are highly variable and often extreme. Therefore, minimizing ecological and economic risks are cornerstones of successful rangeland management. Risk management requires a thorough understanding of the interactive effects of biotic (e.g., plants, herbivores, decomposers) and abiotic (e.g., climate, atmosphere, soils, nutrients) factors that influence the kind, quality, and amount of plants produced.

Climate Diagram—Miles City, MT

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, MT.

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

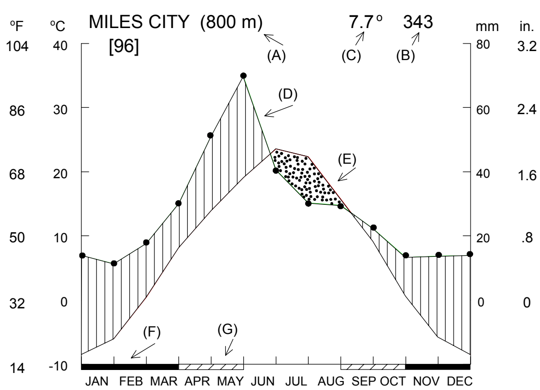


Figure 1. Mean monthly precipitation (mm) (dotted solid line) and temperature (°C) (solid line) for 96-year period indicate mesic spring, early summer, and fall periods (vertical lines) interrupted by late summer and early fall drought (dots).

Findings: A plot of mean monthly precipitation and mean monthly temperature on a graph with unique y-axes (one division = 10°C = 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 in 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 (0.8 inches) of precipitation occurs during April, July, August, September, and October, and less than 20 mm (0.8 inches) occurs during January, February, March, November, and December. Monthly average temperatures are warmer than 20°C (68 °F) 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 rangelands 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 rangelands. 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.

Eighty Years of Vegetation and Landscape Changes in the Northern Great Plains— A Photographic Record

K.D. Klement, R.K. Heitschmidt, and C.E. Kay

Shifts in the composition of plant species are often linked to changes in the structure and function of ecological systems. Detecting such shifts in relatively undisturbed natural systems, such as rangelands and forests, is often difficult because changes occur very slowly and, therefore, are quite subtle. Often, changes aren't recognized because substantial change seldom occurs within a single human generation; rather, readily detectable change usually requires the span of several generations.

This publication is an attempt to provide researchers, naturalists, land managers, policy makers, and the general public with a new awareness of and appreciation for the subtle, yet real changes that have occurred over the past 80 to 90 years in the Northern Great Plains. We recorded the changes by repeating landscape photographs, which we augment with descriptions derived from on-site visits. The challenge to us, as well as our readers, revolves around how we might use the information presented here as a means for improving land stewardship.

The earliest photographs were taken by Dr. Homer Shantz, University of Arizona, from July 14, 1908 to September 1, 1937.

The second set of photos was taken of the original sites from June 13, 1958 to August 18, 1960. Shantz took a portion of these before he died in 1958 while on the road rephotographing the sites. He was accompanied on that trip by Dr. Walter S. Phillips, University of Arizona, who completed the repeat photography task in 1959, with the assistance of University of Arizona student Freeman Smith (now Dr. Freeman Smith, Colorado State University), and in 1960 in the company of his wife, Thelma K. Phillips.

The 1998 photographs were taken from July 21 to August 5, 1998, by Dr. Charles Kay, Utah State University.

Sites were again visited during the summer of 1999 by Keith Klement of the Fort Keogh Livestock and Range Research Laboratory.

The original photographs, first retakes, and associated site descriptions were published by Phillips in 1963 in *Photographic Documentation: Vegetation Changes in Northern Great Plains.* A history of the two earlier photographic expeditions is contained in that publication.

The current publication includes repeat photographs from 42 of Shantz's 81 original sites. We limited our sites to rangelands. For most sites, four photographs are reproduced: (1) Shantz's black and white original, (2) the 1958-1960 black and white retake, (3) a 1998 black and white retake, and (4) a 1998 color retake.

Shantz's and Phillips' original negatives are stored at the University of Arizona Herbarium in Tucson. Kay currently maintains his negatives, which he intends to leave to the Utah State University library in Logan upon his retirement.

It is refreshing to review the photographs and conclude that the general ecological condition of the lands appear to have changed little over the past 75-plus years, with three exceptions. The first exception is that the density and cover of woody plants appears to have increased, particularly with respect to the Ponderosa pine. The second exception concerns changes in plant community structure and species composition due to human intervention (tillage, haying, and road construction, for example). The third exception is those instances where nonindigenous species, particularly yellow sweet clover and crested wheatgrass, have invaded sites by escaping from nearby roadside restoration projects and agronomic plantings. Otherwise, the changes seem subtle.

Relevant Publications:

Klement, K.D., R.K. Heitschmidt, and C.E. Kay. 2001. Eighty years of vegetation and landscape changes in the Northern Great Plains—A photographic record. USDA-ARS Conservation Research Report No. 45. Pp. 91.

A copy of the full report may be obtained from LARRL by emailing us at reprints@larrl.ars.usda.gov, calling us at: 406-232-8200, or writing to us at:

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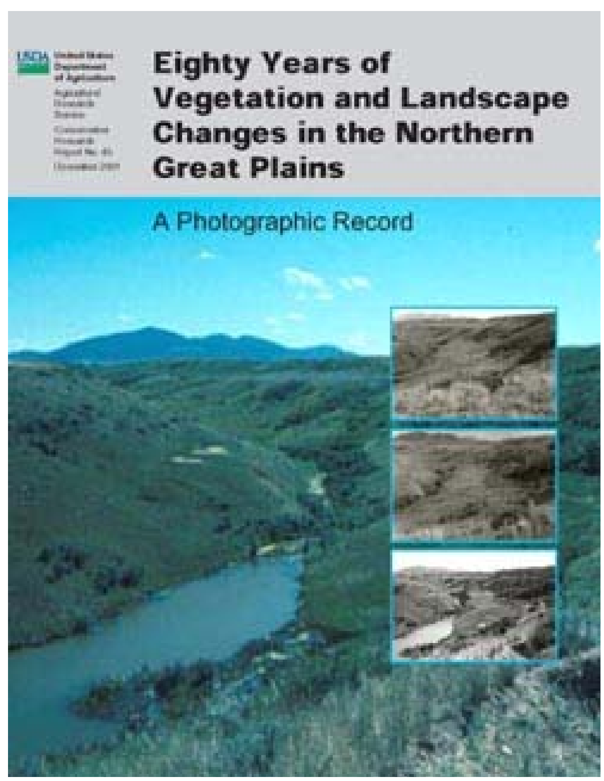


Measuring Carbon Fluxes over Northern Great Plains Rangelands

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, there are limited estimates of their potential role as a source or sink for atmospheric carbon. Also lacking 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.

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

Procedures: Effects of seasonal grazing on carbon dioxide flux were estimated on small plots located on a silty range site in the mixed-grass prairie with an Eapa fine loam soil. Vegetation was dominated by perennial cool-season grasses (western wheatgrass and Sandberg bluegrass) and sedges (thread-leaf sedge), perennial warm-season grasses (blue grama and buffalograss), sageworts, and forbs. Three treatments were imposed using sheep to graze replicated plots. The treatments were: no grazing, intensively grazed in mid-May, and intensively grazed in mid-July. The study was conducted for three years (1996, 1997, and 1998). From mid-April to mid-October data were collected at about 30-day intervals. Data recorded include: standing crop, leaf area on clipped and non-clipped 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. Carbon dioxide concentration was measured over the plant canopy and soil in a closed chamber (35.3 ft^3) connected to an infrared gas analyzer. Carbon dioxide measurements were made at 0800, 1200, 1600, and 2400 hours.

Findings: Green standing crop on unclipped control plots ranged from 958 to 238 lbs/acre in 1996, 594 to 171 lbs/acre in 1997, and 415 to 177 lbs/acre in 1998 (Table 1). Perennial cool-season grasses and sedges generally made up more than 60% of the green standing crop during April through July each year. Perennial warm-season grasses and sageworts begin to increase in dominance during July. During grazing events an average of 68 to 78% of the green standing crop was removed. Reducing the green standing crop reduced the uptake of carbon dioxide by an average of 175% in May and 109% in July. Carbon dioxide uptake was reduced only 19% on adjacent ungrazed plots.

Uptake and release of carbon dioxide are dependent upon the environment (precipitation and temperature) as well as the growth stage of plants. Precipitation values in Figure 1, from Frank Wiley Field, show a general trend in precipitation for the years of the study. Carbon dioxide uptake (Figure 2) is greatest during spring and early summer when there is adequate precipitation and maximum amounts of green biomass (Table 1).

Some among-year variation occurred in carbon dioxide uptake due to the amount and distribution of precipitation. However, initial findings show carbon dioxide uptake, averaged over the measurement times and three years, was reduced for up to 30 days after grazing in May and July (Figure 2). Carbon dioxide uptake appeared to increase slightly on May grazed plots compared to control plots in July and August, and this increase was probably due to regrowth that occurred after grazing. Residual effects of grazing, however, declined in autumn with the onset of plant maturation. Thus, weather, particularly precipitation and temperature, appear to exert a primary control on carbon dioxide exchange.

Future Direction: Data analysis is complete and manuscripts are being prepared from this study. Another study will be started on an adjacent site in 2003 to evaluate the effect of intensive and moderate grazing during May and June on carbon dioxide flux. Information from these studies should provide improved estimates of the contribution of Northern Great Plains rangelands and associated grazing practices to carbon dioxide flux and ultimately to global warming.

Table 1. Estimates of green biomass (lbs/acre) on treated plots on selected dates 1996, 1997, and 1998

Year/ treatment	Date April	May	June	July	Aug	Sept	Oct
1996							
Control	-	597	958	673	353	238	172
May	-	-	338	421	300	151	81
July	-	-	-	-	76	68	43
1997							
Control	171	362	594	493	353	252	170
May	171	367	351	364	299	121	116
July	127	270	402	412	99	71	52
1998							
Control	177	403	415	470	285	288	99
May	168	372	104	332	288	136	93
July	144	300	283	362	38	43	22

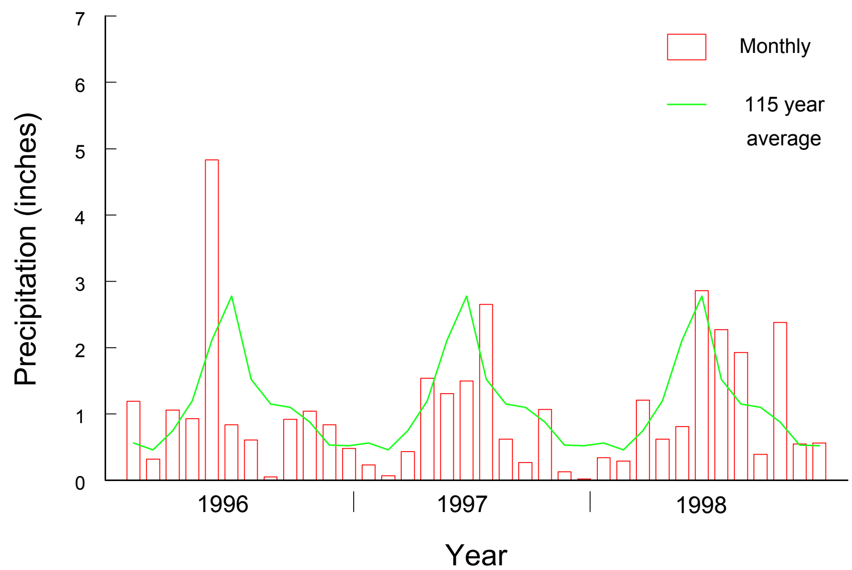


Figure 1. Actual and long-term average precipitation for Frank Wiley Airfield, Miles City, MT.

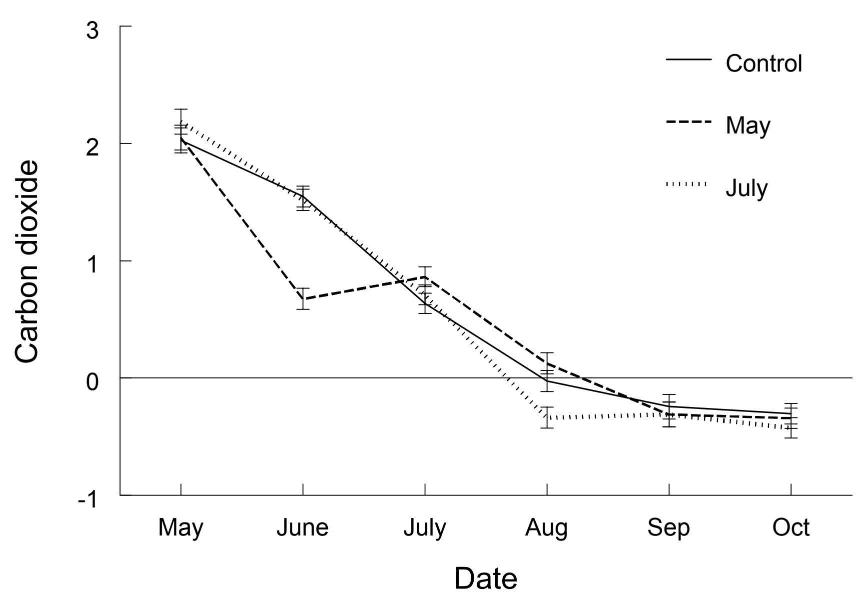


Figure 2. Carbon dioxide flux measured over two 10.8 square foot plots that were either ungrazed or grazed intensively in May or July.

Evaluation of Experimental and Released Cool-Season Grass Varieties in the Northern Great Plains

M.R. Haferkamp

Problem: Seeded perennial cool-season grasses can be used for restoring burned and disturbed area on rangelands, managing noxious weeds, and extending the grazing season for large herbivores. New and improved plant materials are continually needed to enhance seeding success. The present study was conducted in cooperation with the USDA-ARS Forage and Range Research Laboratory, Logan, UT, to evaluate the performance of several native and introduced cool-season grasses in the Northern Great Plains.

Procedures: The nursery is located on a Yamacall loam with 0-2% slope. Seeding was accomplished on mechanically fallowed, weed-free seedbeds with a drill equipped with double-disk furrow openers and depth band regulators. Seeds were placed from 0.5 to 0.75 inches below the soil surface at a rate of about 2.5 seeds per inch. Individual plots consisted of drill rows spaced 1 foot apart. Plots, 12 by 50 feet, were arranged in a randomized block design with four blocks. Weeds were controlled chemically in 1995, but no fertilizer has been applied to these plots. Standing dead was mowed to a 3 to 4 inch stubble in autumn or rarely early spring.

Dry matter yields of current year's forage were determined by clipping to ground level during the weeks of 06 June 1997, 18 June 1998, 09 June 1999, 06 July 2000, 26 June 2001, and 24 June 2002. Two or three quadrats were sampled in each plot with total sample area per plot ranging from 5.4 to 32.7 ft^2 depending upon the year.

Findings: Above average precipitation in September and October 1994 and above or near average precipitation in March through July 1995 were ideal for establishment and growth of the seeded grasses. Environmental conditions, particularly precipitation amounts and time of occurrence, varied among years. September through November precipitation was 15% greater than the 115-year average in 1996, 41% less in 1997, 32% greater in 1998, 39% less in 1999, 15% greater in 2000, and 57% less in 2001 (Figure 1). March through May precipitation was 21% less than the 115-year average in 1997, 35% less in 1998, and 8% greater in 1999. March through June precipitation was 42% less than the long-term average in 2000, 10% greater in 2001, and 28% less in 2002. Grasshopper populations were also high in 1998, 1999, and 2000.

Lack of precipitation in autumn and spring depressed yields of many varieties during 1998, 2000, and 2002 (Table 1). The decrease in 1998 compared to 1997 and 1999 was not as obvious as the decreases in 2000 and 2002 compared to 2001. The lack of difference between yields in 1998 and 1999 may have been masked by the fact that production of some grasses begin to decline after the third year. Examples of varieties that declined in production during the study include several of the thickspike wheatgrasses, Snakeriver wheatgrass, and bluebunch wheatgrass.

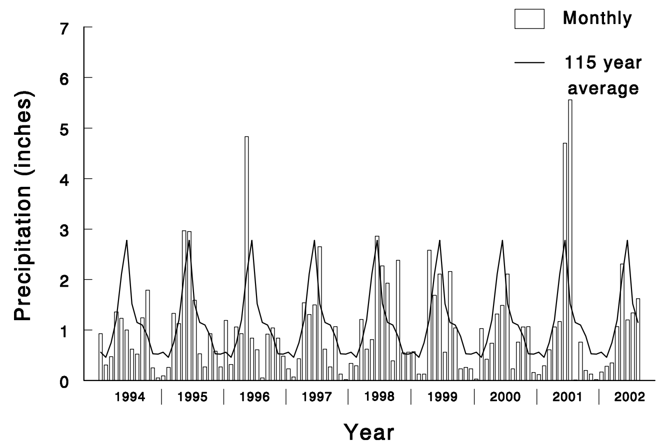


Figure 1. Actual and long-term average precipitation for Frank Wiley Airfield, Miles City, MT.

In 1999 Hycrest Original was the only crested wheatgrass variety more productive than Nordan. Swift and Mandan 1831 were the most productive Russian wildryes. Vavilov Siberian wheatgrass was more productive than P-27. Sodar and Critana were the most productive thickspike wheatgrasses. Both varieties of Snakeriver wheatgrass, western wheatgrass, and bluebunch wheatgrass performed equally well by 1999. Stands of bluebunch wheatgrass and Bannock and SL hybrid thickspike wheatgrass declined during the early part of the trial. Swift and Mandan 1831 Russian wildrye and Vavilov Siberian wheatgrass yielded particularly well in 1999.

By 2002 the Hycrest Original and Hycrest 2 were the most productive crested wheatgrasses. No clear statistical winner occurred among the Russian wildryes and other wheatgrass species.

These data clearly show that some released and experimental varieties are more adapted than others to this site on the Northern Great Plains. Although some varieties of crested wheatgrass and Russian wildrye have the potential to produce large amounts of forage when precipitation is plentiful, production will decline in dry years.

Future Directions: Cooperative nursery evaluations are being continued at Fort Keogh with USDA-ARS Lincoln, NE, Logan, UT, and Mandan, ND, as well as, Ducks Unlimited-Canada. New studies were planted in autumn 1999 and spring 2001.

Relevant Publications:

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

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.

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 (*Pseudoroegneria 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., 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., 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. and E.E. Grings. 2000. To seed or not to seed... Montana Farmer Stockman 88:30-31.

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

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2001. Livestock performance on seeded forages in the Northern Great Plains. Proc. West. Sec. Am. Soc. Anim. Sci. 52:326-328.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2002. Quality and persistence of cool-season forages in the Northern Great Plains. J. Range Manage. 55:482-487.

Table 1. Standing crop (pounds/acre) of cool-season grasses growing in the nursery 1997 through 2002

	Year					
Species/variety	1997	1998	1999	2000	2001	2002
Crested Wheatgrass	- - - - - - - - - - Pounds/Acre - - - - - - - - - -					
Nordan	1731	1575	1891	549	1567	954
Hycrest Original	1893	1872	2635	528	1931	1722
Hycrest 2	1825	1543	2194	701	871	1712
Ephraim	2019	820	2171	326	1374	414
Douglas	1742	1245	1418	363	1494	21
Russian Wildrye						
Swift	2174	2130	3007	1232	1758	909
Bozoisky	1048	2107	2293	688	1560	1173
Bozoisky Hybrid	1671	1372	2258	661	1444	1113
Synthetic A	1752	1527	1673	601	1582	746
Mankota	1697	2264	2623	849	1518	843
Mandan 1831	2047	3208	3061	765	2120	1112
Mandan 1881	1882	1723	2040	581	1504	997
Tetraploid	1662	1531	2011	803	1590	1110
Siberian Wheatgrass						
P-27	2277	1754	2218	540	1519	600
Vavilov	2398	1781	2885	530	1631	495
Thickspike Wheatgrass						
Sodar	1256	1466	1649	528	862	594
Critana	1385	1413	1859	535	930	526
Bannock	1218	1078	642	54	330	138
SL 1 Hybrid	1648	1197	490	204	39	22
Snakeriver Wheatgrass						
Secar	1736	1149	1247	97	185	32
E 20	722	1456	1005	65	145	35
Western Wheatgrass						
Rosana	1031	1039	1347	565	1059	755
Rodan	1030	933	1149	480	599	623
Bluebunch Wheatgrass						
Goldar	1107	991	497	0	7	0
BBP2	1172	705	2	0	2	4
Standard Error	232	189	189	232	232	232

Annual Bromes—Good or Bad?

M.R. Haferkamp

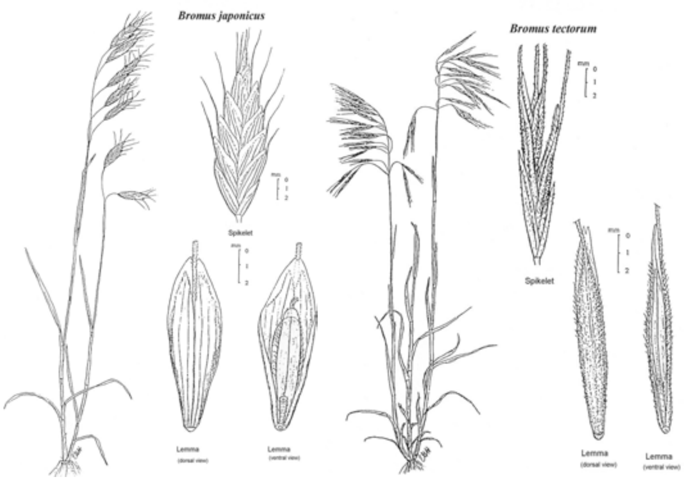


Figure 1. Illustrations of Japanese and downy brome plants, spikelets, and florets (Courtesy of Emerenciana G. Hurd).

Introduction

Are annual bromes good or bad? Japanese brome (*Bromus japonicus* Thunb) and downy brome (*B. tectorum* L.), alien weedy cool-season annual grasses, have invaded thousands of acres of the Northern Great Plains, Great Basin, California Annual Grasslands, and Palouse Prairie. What is the impact of annual bromes on infested range lands?

Personal experiences with annual bromes

Colorado and South Dakota: My first encounter with annual bromes was in the mid 1960s while attending Colorado State University in Fort Collins. At that time I did not realize that working with annual bromes would become such a large part of my future research career. As a student, I saw downy brome on a daily basis during laboratory assignments and on part-time jobs. I encountered Japanese brome in South Dakota while working with Professor Tex Lewis. By 1968, Japanese brome covered relatively large areas in the exclosures and lightly grazed pastures at the Cottonwood Experimental range in western South Dakota.

Oregon: I began research work with annual bromes in 1981 when I moved to Burns. Downy brome was one of the major species we had to control before establishing successful range seedings in the Northern Great Basin and Palouse Prairie. Annual bromes have invaded vast acreages in the Great Basin and Palouse Prairie. These acreages are maintained in part by the cyclic fire regime of the regions. Establishing autumn seedings of cool-season grasses was enhanced by reducing competition from annual bromes. We generally were successful when we prepared seedbeds by a combination of (1) reducing brome seed yields with fire in the spring or early summer and (2) reducing density of emerging brome seedlings after autumn rains with herbicides or tillage.

Montana: I moved to Miles City during a drought in 1988 and saw few annual bromes in this area of the Northern Great Plains until 1989, a year with above average annual precipitation. It became apparent, after looking at published literature in the late 1980s, that annual bromes did not have much impact in the region before the mid 1950s. However, data collected in the 1980s clearly indicated that annual bromes could provide a large proportion of the spring forage produced in the Northern Great Plains. As with most annual grasses, herbage production from annual bromes is erratic from year to year (Table 1). Early maturation of annual brome plants impacts rangelands in two main ways. Brown mature herbage is poor quality for grazing livestock and provides fine fuel for fires.

Gleanings from the literature

The literature search also exposed many gaps in information on annual bromes in the Northern Great Plains. Particularly missing was information on the impact of annual bromes on production of native vegetation and livestock. We also did not know if annual brome seeds produced in the Northern Great Plains germinated and responded to environmental factors similarly to bromes growing in other regions of the United States. I will describe some findings from a series of studies on annual bromes conducted in the Northern Great Plains at the Fort Keogh Livestock and Range Research Laboratory near Miles City, MT.

Research Findings

How does environment affect establishment and growth of annual bromes?

Abundance of brome depends on availability of seed, amount and distribution of rainfall, temperature, and availability of soil nitrogen. Brome is most abundant in years following wet autumns and most productive in years with abundant autumn and spring rainfall. Cool temperatures during the growing season will prolong growth of annual bromes, and adding nitrogen to the soil increases forage production as shown in some fertilizer studies in the region.

All of the environmental factors work together to impact annual brome production. While it is relatively easy to determine whether density of annual brome plants will be great in a given year, it is difficult to know how much and how long forage will be produced by the bromes.

What conditions promote seed germination and seedling establishment?

More than 10,000 annual brome seeds can be present in a square yard in the mixed-grass prairie of the Northern Great Plains. Seeds will generally germinate over a wide range of temperatures that often occur in late summer and autumn, but soils usually need to be moist for 3 to 5 days for seeds to germinate. Litter enhances germination and seedling emergence by conserving soil water. Seeds can germinate in spring, particularly after dry autumn and winter periods, when soil water is available during spring.

The high level of germination exhibited by Japanese brome in our studies suggests a large portion of the ripe seeds will germinate with available water during late summer and early autumn. However, a percentage of the seeds that do not germinate by late-September can become dormant when water is taken up at or below 32°F. This dormant state can last through the next winter, spring, and summer. This characteristic aids annual brome's persistence on rangelands, because seedlings emerging in August and September in any year likely come from two seed crops, the current and previous years. Emerged seedlings will over-winter and begin growth in early spring.

Harvesting stands of Japanese brome for hay may reduce the seed bank in one area and increase the seed bank where the hay is fed. We found that Japanese brome seed could germinate when harvested green in mid-June. **It is best to feed Japanese brome hay only on brome infested areas.**

Do annual bromes compete with established native perennial grasses?

Annual bromes add to the total forage base at the expense of perennial grasses. When we removed annual bromes from mixed-grass prairie communities, total yields were reduced an average of 23% and western wheatgrass yields increased 23%. The short-term increase in production of western wheatgrass was due to an increase in number of shoots, rather than an increase in weight of individual shoots. The ability for brome to suppress forage production can be expected over a wide array of environmental conditions with variable late spring and early summer precipitation (e.g., 4 to 15 inches) and variation in total forage production (e.g., 1,100 to 2,100 pounds/acre).

Do annual bromes impact livestock performance on rangelands?

Many studies have shown a decline in weight gains of stocker cattle as the grazing season progresses from spring to autumn in the Northern Great Plains. Two questions come to mind. How much of this decline is due to maturation and senescence of perennial grasses? How much of the decline is due to the presence of large amounts of early maturing annual bromes?

When we reduced the amount of annual brome chemically, gains of stocker cattle were increased from 2.02 to 2.29 pounds/head/day and from 15.6 to 18.1 pounds/acre from May to September, 1993-1995. We think a portion of the increase in gain was due to an increase in crude protein of diets. Crude protein in diets was increased from 12.6% to 14.2% due to both a shift in botanical composition of diets as well as an increase in crude protein concentration in response to the herbicide. Percentage of annual grasses was reduced in the diets in most years, and replaced by a variety of species (e.g., western wheatgrass, forbs, and blue grama).

Will bromes always affect livestock performance on rangelands?

The 16% increase in gains of stocker cattle obtained with reduction of annual bromes can occur on other Northern Great Plains ranges. However, results following brome reduction will vary depending on the magnitude of annual production of bromes and the distribution of bromes within a given pasture. Untreated pastures in our study (1993-1995) were uniformly infested with annual bromes, however production of annual bromes was relatively small compared to other years (Table 1). Increase in livestock performance may have been greater if a greater brome production was removed, but it might have been smaller if cattle were grazing large pastures with spotty distribution of bromes. When bromes are less abundant or abundant in patches, livestock can more easily select perennial species in their diets.

What will happen on brome infested ranges in the future?

We do not anticipate an ecological shift of northern mixed-grass prairies toward an annual grass dominance. We know that the amount and abundance of annual bromes occurring on Northern Great Plains rangeland is cyclic and depends on the seed bank, temperature, and amount and distribution of precipitation. In addition, western wheatgrass and blue grama, two of the dominant perennial grasses, reproduce vegetatively and have long life spans. These species effectively buffer the impacts of Japanese and downy brome in mixed-grass prairie communities, particularly where grazing management strategies maintain healthy-vigorous stands of native mixed-grass prairie vegetation. This is in contrast to the overwhelming successful invasion of downy brome into areas dominated by shrubs and bunch grasses in the Intermountain West.

What are some alternatives for managing annual bromes?

Suppression of brome requires environmental and/or managerial reduction of the annual brome seed bank. Even after 2 years of suppression by burning, herbicides, or grazing the seed bank may contain enough seed to maintain brome populations or allow an increase in its abundance.

Grazing: The best management practice is to graze brome infested ranges in early spring. This way you are negatively impacting the brome while using available forage. Cattle should be removed while adequate soil water is available for growth of perennial grasses. This practice will allow management of but not eradication of bromes. Reducing seed production by defoliation should be an effective method of interrupting the life cycle of annual bromes. Actually, we found you can reduce above- and below-ground biomass and seed production of Japanese brome plants with frequent-intensive clipping in controlled environments. In the field, the brome population is reduced both through reduction in the amount of seed and the amount of mulch or litter.

The biggest challenge to control via defoliation by grazing or mowing is that a rather narrow window exists in early spring when defoliation can suppress annual brome growth, seed production, and mulch buildup. This approach would require high density grazing for a short duration or carefully timed mowing, during which time bromes would be closely defoliated and/or seed production prevented. Uniformly defoliating brome plants with grazing or mowing and precisely timing defoliation to reduce selection of perennial grasses and allowing the perennials adequate time to recover from defoliation before the end of the growing season is not easily accomplished on any rangelands.

Unfortunately, terminating grazing or mowing when soil water is available for growth of associated perennial grasses may also prove advantageous for annual bromes. It is unlikely all annual brome plants and shoots will be grazed. Consequently, some annual brome plants will always be present to produce viable seed and replenish the seed bank.

Burning: Findings of other researchers have shown increases in forage yields of perennial grasses after suppression of Japanese brome with burning. Burning kills seedlings, reduces seed, and removes mulch. Generally, greater reduction of annual bromes can be expected from burning when precipitation is below normal following the year of burning. This phenomena is a result of reduction in litter accumulation, which will reduce annual brome recruitment, seed production, and seed banks.

Herbicides: Some chemicals that would be beneficial in controlling brome (e.g., atrazine) are no longer labeled for use on rangelands. Wyoming researchers reported promising annual brome control in the late 1990s with both glyphosate and paraquat which are available. Care must be used in choosing times of application to reduce damage to associated desirable perennial grasses.

Management Implications

Annual bromes will persist on Northern Great Plains ranges. Maintenance of a viable livestock industry will require special management skills because this region is characterized by large and rapid changes in forage production, resulting from periods of above and below average precipitation and the invasion of alien weeds. You will have to decide if annual bromes are a problem on your operation. Can they be controlled, or better yet, can they be economically controlled? It is important to determine the botanical composition of pastures and plan their use based on livestock nutrient requirements and the potential of plant species to provide the required nutrients. This inventory is critical for devising management strategies to maximize efficiency of utilization of Northern Great Plains rangelands.

Table 1. Ungrazed spring forage yield sampled in May and June at Fort Keogh

	Species groups					
	Grasses					
Year	W. wheatgrass[1] S. bluegrass	Annual	Other	Sedges	Forbs	Total
	(pounds/acre)					
1983	239	343	210	25	104	922
1984	170	301	60	16	27	573
1985	196	170	52	11	52	480
1986	581	183	74	21	89	950
1987	434	236	59	18	69	816
1988	246	23	53	6	36	364
1989	382	373	51	11	57	822
1990	468	452	60	27	51	1,057
1991	310	632	33	0	19	994
1992	267	242	32	0	20	560
1993	302	126	79	24	75	608
1994	522	28	97	4	46	695
1995	433	117	79	29	82	740

[1] Western wheatgrass and Sandberg bluegrass.

Relevant Publications:

Haferkamp, M.R. 2001. Annual bromes - good or bad? Rangelands 23:32-35.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, M.D. MacNeil, and M.G. Karl. 2001. Suppression of annual bromes impacts rangeland: Animal responses. J. Range. Manage. 54:663-668.

Haferkamp, M.R. and R.K. Heitschmidt. 1999. Japanese brome impacts on western wheatgrass in Northern Great Plains rangelands: an update. Great Plains Res. 9:315-327.

Haferkamp, M.R., R.K. Heitschmidt, E.E. Grings, M.D. MacNeil, and M.G. Karl. 2001. Suppression of annual bromes impacts rangeland: Vegetation responses. J. Range. Manage. 54:656-662.

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

Haferkamp, M.R., M.G. Karl, and M.D. MacNeil. 1994. Influence of storage, temperature, and light on germination of Japanese brome seed. J. Range Manage. 47:140-144.

Haferkamp, M.R., M.D. MacNeil, and M.G. Karl. 1996. Induction of secondary dormancy in Japanese brome (*Bromus japonicus*), p. 199-200. *In*: N. West (ed.), Proc. Fifth Inter. Rangeland Cong. 23-28 July 1995, Salt Lake City, UT.

Haferkamp, M.R., D. Palmquist, J.A. Young, and M.D. MacNeil. 1995. Influence of temperature on germination of Japanese brome seed. J. Range Manage. 48:264-266.

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.

Published previously in *Rangelands.* 2001. 23(5):32-35.

Effects of Sheep Grazing on Grasshopper Population Dynamics and Rangeland Vegetation

D.H. Branson and M.R. Haferkamp

Problem: In much of the Northern Great Plains, grasshopper populations tend to increase with grazing intensity, drought, and bare ground. Grasshopper outbreaks on rangeland result in competition with livestock for limited vegetation and lead to dispersal into crops. Traditional pesticide control programs for rangeland grasshoppers are often ineffective in protecting vegetation, as well as economically and environmentally unsound. Although it appears differing types of livestock grazing can lead to either increases or decreases in grasshopper populations, we don't understand how the timing and intensity of livestock grazing affects grasshopper population fluctuations. Differences in livestock grazing can affect factors such as microclimate conditions for grasshoppers and vegetation characteristics that can affect grasshopper population dynamics. The goal of this study was to examine how the timing and intensity of sheep grazing affected grasshopper population dynamics, vegetation characteristics, and nitrogen availability. A secondary goal was to examine how outbreak densities of grasshoppers affect rangeland vegetation and grasshopper populations both during an outbreak and in the year following it.

Procedures: The experiment was conducted on a site highly dominated by western wheatgrass. There was a severe grasshopper outbreak in 2000, with over 100 grasshoppers per square yard in early summer. Cages made from mesh screening (9 x 12 foot) were used in the experiment. Livestock grazing treatments consisted of no sheep grazing, early season grazing, late season grazing, and repeated sheep grazing. Each of the grazing treatments had cages initiated at the field density of 110 grasshoppers per square yard and at a reduced density of 35 grasshoppers per square yard. Grazing treatments were accomplished by placing two ewes in a given cage for approximately 1 hour. Grasshopper populations in the cages were assessed every 7 to 10 days. Grass biomass was sampled biweekly in uncaged areas and inside each cage at the end of the experiment and analyzed for crude protein content. Ion exchange capsules were buried in each cage to assess the availability of nitrogen for plants. In 2001, the number of grasshoppers hatching in each cage was measured.

Findings: In 2000, grasshopper numbers outside cages dropped rapidly from 110 per square yard to less than 1 per square yard over the course of a month (Figure 1). Grasshopper survival in the experiment was affected more by initial grasshopper density than by grazing treatments. Measurements of cage vegetation, grasshopper survival, and grasshopper size were all consistent with higher food limitation of grasshoppers in the field density treatment cages. Although sheep grazing did not have large effects on grasshopper survival in cages, it appeared to increase food limitation for grasshoppers as surviving grasshoppers were smaller. Additional effects of sheep grazing on grasshopper populations likely exist when grasshoppers are less abundant, as even the reduced grasshopper density treatment was representative of an extreme grasshopper outbreak.

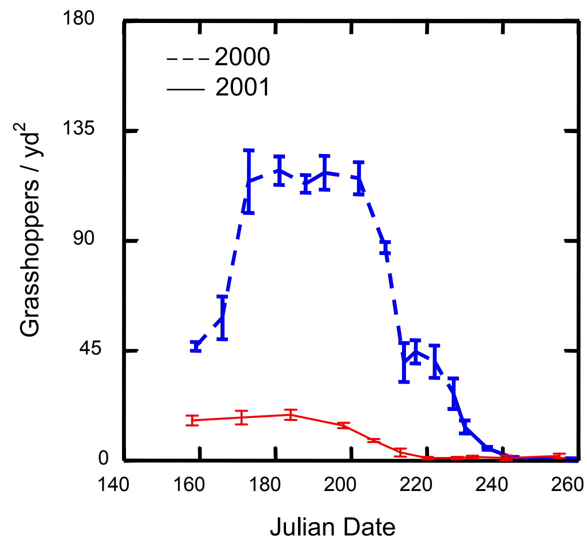


Figure 1. Grasshopper densities in uncaged control areas in 2000 (– –) and 2001 (—). (July 1 ~ Julian Date 183).

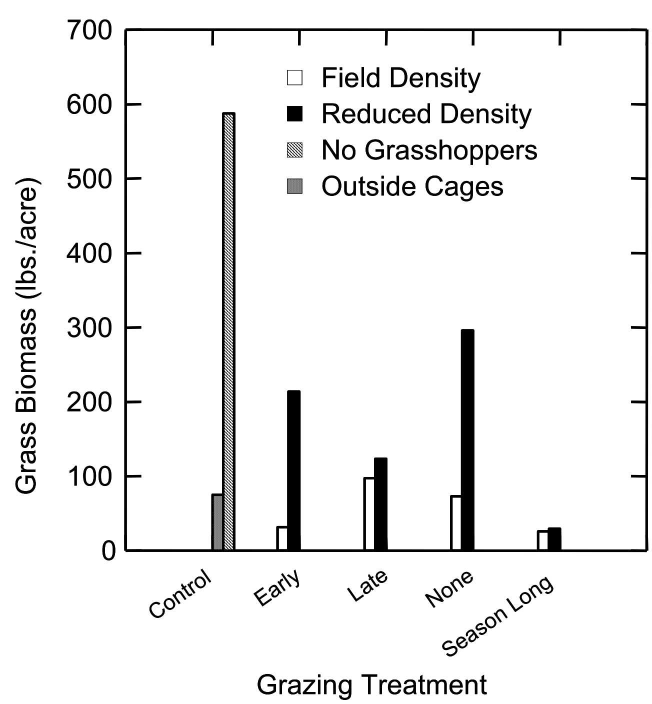


Figure 2. Green grass biomass remaining in cages and uncaged control areas at the end of the summer in 2000.

Grasshoppers removed much of the available grass biomass both in uncaged areas and in cages with field grasshopper densities (Figure 2). Cages with no grasshoppers had over eight times more grass remaining at the end of the summer than in cages initiated with 110 grasshoppers per yd^2 (Figure 2). Field density cages had less grass remaining and lower crude protein content of grasses than reduced density cages. The amount of grass removed by grasshoppers in 2000 was much higher than that removed by any of the sheep grazing treatments. During a severe grasshopper outbreak, grasshoppers had a larger effect on rangeland vegetation than livestock grazing.

Grasshopper populations at the site crashed in 2001, as densities were more than six times lower than in 2000 (Figure 1). Some grasshopper species were more strongly affected by the severe food limitation in 2000. For example, the large headed grasshopper, a late season species, declined from nearly 80% of the grasshopper community to only 15% in 2001. Few grasshoppers were able to lay eggs in the field density cages in 2000 (Figure 3) before they died, as fewer grasshoppers hatched in 2001 in field density cages than in cages with reduced densities in 2000. There were no large effects of sheep grazing treatments on the number of grasshoppers hatching in cages in 2001 (Figure 3).

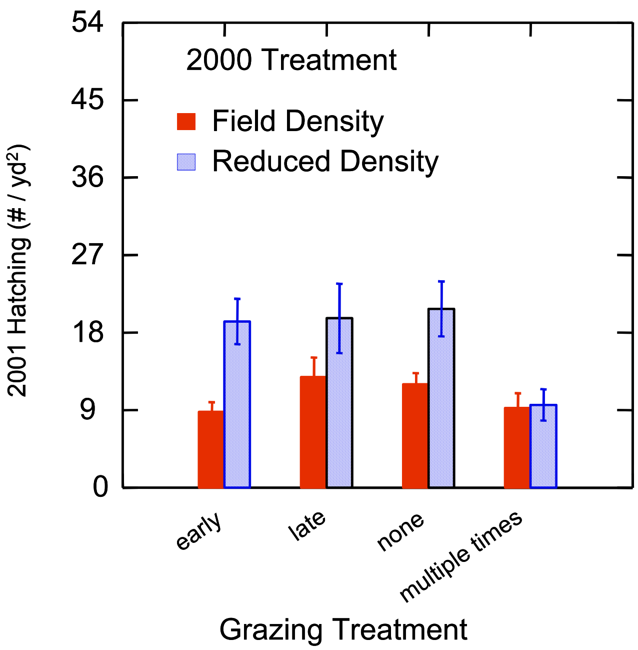


Figure 3. 2001 grasshopper hatchout in each field season treatment from 2000.

Although there was no effect of sheep grazing on crude protein content of remaining grass in 2000, cages with sheep grazing had higher grass crude protein content in 2001. Cages with sheep grazing also had increased amounts of nitrate in the ion-exchange resin capsules, indicating more nitrogen was available for plants in 2001. Therefore, livestock grazing affected vegetation quality and nitrogen availability in the second year of the experiment. Although sheep grazing did not have large effects on grasshopper population dynamics during a severe grasshopper outbreak, the effects of livestock grazing on vegetation quality and nitrogen availability evident in the second year of the experiment are likely to indirectly affect grasshopper population dynamics.

Future Direction:
These experiments are continuing and will address the effects changes in plant physiology resulting from livestock grazing have on patterns of grasshopper herbivory.

Relevant Publications:
Branson, D.H. and M.H. Haferkamp. 2002. Multi-year effects of the timing and intensity of sheep grazing on grasshopper populations. Soc. Range Manage. Abstracts 55: 288. (Abstr.).

Branson, D.H. and M.H. Haferkamp. 2002. Grasshopper and sheep herbivory impacts on grasshopper population dynamics, vegetation and nitrogen availability: Results from a two year experiment. Bull. Ecol. Soc. Amer. 83:S324. (Abstr.).

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 livestock producers. Periods of limited forage quality and/or quantity exist due to temperature extremes, limited water (late summer and fall) or combinations of the two. Strategies can be devised to overcome these limitations to animal production. Programs may include the use of complementary forages, provision of supplemental feed, selection of livestock to match the environment, and variation in the timing of resource use.

In addition to management effects on the efficiency of livestock production, the impacts on ecological health must be evaluated. Indicators of rangeland health typically lack the sensitivity to detect small changes and rangelands are well-adapted to most short-term disturbances. Therefore, long-term studies are often required to determine management effects on ecological health. Government-sponsored laboratories, such as Fort Keogh, have the unusual opportunities to make long-term commitments to this type of research.

Impacts of Various Livestock Grazing Strategies on Northern Great Plains Rangelands

L.T. Vermeire, 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 preferred 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 October 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 treatment 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: Cattle exclosures have increased in total standing crop. However, current year's standing crop and species composition appear similar on grazed and non-grazed sites throughout the 8 years of treatments.

Current year's standing crop and species composition have been similar among grazing systems with moderate stocking rates. During the 6 years of treatment, vegetation changes have been more strongly linked with annual variation in environmental conditions than the attributes of any particular grazing system. The heavily stocked treatment has reduced standing crop, relative to the moderately stocked grazing systems, but has not expressed a change in species composition to date.

Future Direction: These studies are designed to continue indefinitely because grazing effects may become apparent only after long periods (>20 years).

Relevant Publications: None to date (September 2002).

Livestock Performance on Seeded Cool-Season Forages

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

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 during early spring and autumn. Many varieties 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 varieties 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 varieties were compared in haying and grazing systems. Their ranking in the two systems differed. Thus, grazing trials are needed before release of varieties for commercial use. The goal of this project was to evaluate introduced and native varieties 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 autumn 1994. Forages were being evaluated for productivity, quality, stand survival, and animal performance.

Yearling cattle grazed the pastures from 9 May to 12 June 1997, 24 April 1998 to15 June 1998, and 27 April to 18 June 1999. They were weighed and forage 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 was in cooperation with the Forage and Range Research Laboratory in Logan, UT.

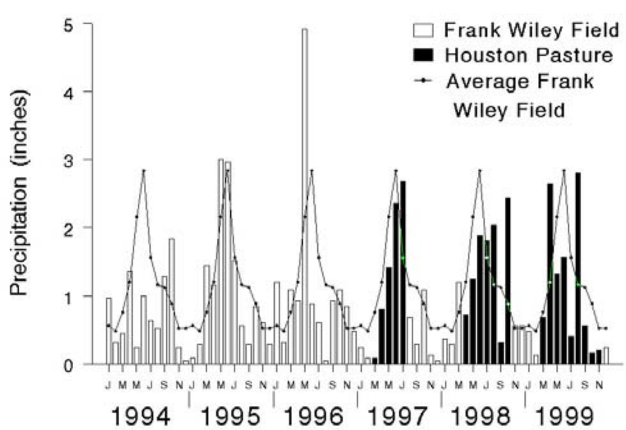


Figure 1. Precipitation from 1994-1999 and the average.

Findings: *Impact of environment* - Productive stands were established for each species following the dormant seeding in late fall 1994. The excellent establishment of seeded stands was partially facilitated by greater than or near average amounts of precipitation in March through July 1995 (Figure 1). In contrast, precipitation was less than the long-term average in April through June and August through October 1996. This lack of precipitation resulted in a partial die off of Luna stands, particularly on elevated portions of the pastures. We planned to begin grazing pastures in April 1997, but less than average precipitation from February through June 1997 slowed plant growth on seeded pastures. Thus, the 1997 trial was limited to the period from 9 May to 12 June. Greater than average precipitation during March 1998 and April 1999 maintained good plant growth and allowed grazing from April to June during each of these years.

Growth and persistence of grasses - Persistence of seeded stands was partially evaluated by comparing the amount of green biomass of seeded species in the spring standing crop. Hycrest produced the largest standing crop in spring 1997 and 1998. However, by spring 1999 standing crops were similar among all three seeded grasses (Table 1). Forbs were most productive on the Hycrest pastures in 1999. This finding combined with the decrease in standing crop of Hycrest in 1999 suggested the Hycrest stand may have thinned. Standing crop of Luna and Rosana were similar among years. Dead biomass, which simply reflects the combination of forage remaining after the grazing season plus that which was produced after cattle were removed, averaged over 900 lbs/acre in 1998 in both the Hycrest and Rosana pastures. This large amount resulted from greater than average precipitation in July and October 1997 (Figure 1).

Table 1. Means for spring standing crops; standard errors equal ± 73 for seeded species, ± 32 for forbs, and ± 99 for standing dead

Groups/Years	Hycrest	Luna	Rosana
	-------	(lbs/acre)	-------
Seeded species			
1997-May	814	400	543
1998-April	1092	607	670
1999-April	551	530	646
Forbs			
1997-May	128	121	163
1998-April	15	73	5
1999-April	233	106	86
Standing dead			
1997-May	595	473	575
1998-April	928	791	1382
1999-April	804	791	382

Standing crops of all three seeded species had declined during the grazing period to near 450 lbs/acre in June 1997 and 775 lbs/acre in June 1999, and standing crops were similar among species for these two periods (Table 2). In contrast, over 1400 lbs/acre of Hycrest remained in June 1998, which was significantly greater than the 900 lbs/acre remaining on Luna and 800 lbs/acre remaining on Rosana pastures. Standing crop of other plant species was less than 300 lbs/acre through June 1998 for all species. However, a trend of increasing amounts of other species began for all three treatment species, but especially for Luna pastures in June 1997, continued through 1998, and was significant in 1999.

Table 2. Means for early spring and summer standing crops; standard errors equal ±169 for seeded species and ± 77 for other species

Groups/Dates	Hycrest	Luna	Rosana
	- - - - - - - - (lbs/acre) - - - - - - -		
Seeded			
June 1997	476	295	419
May 1998	2271	2114	1607
June 1998	1467	922	794
May 1999	1156	795	1313
June 1999	805	626	906
Other species			
June 1997	12	39	4
May 1998	24	137	26
June 1998	92	304	65
May 1999	355	942	266
June 1999	309	863	209

Livestock performance **-** Daily gains (Table 3) and gains per acre (65 lbs/acre) were similar among seeded grasses in 1997. Daily gains were greater on Hycrest than Rosana in 1998 (Table 3). This could be related to the greater amount of standing dead observed in the Rosana pastures in spring 1998. Gains per acre were greater for Hycrest (159 lbs/acre) than for both Luna and Rosana (average = 132 lbs/acre). This may reflect the lowered digestibility observed for Rosana compared to Hycrest in 1998. Daily gains per head (Table 3) and gains per acre on Hycrest and Rosana (93 lbs/acre)were greater than on Luna (64 lbs/acre) in1999.

Table 3. Means for average daily gain of yearling cattle; standard errors equal ± 0.07 for species, ± 0.17 for year, and ± 0.09 for species by year interaction

Year	Hycrest	Luna	Rosana	Mean
	- - - - - - - (lbs·head^{-1} ·day^{-1}) - - - - - - - - -			
1997	2.5	2.3	2.8	2.5
1998	2.8	2.4	2.3	2.5
1999	1.6	1.2	1.7	1.5
Mean	2.3	2.0	2.3	

Steer gains in 1997 and 1998 were 40% greater than heifer gains in 1999 (Table 3). Gains per acre for Hycrest and Rosana were greatest in 1998, intermediate in 1999, and least in 1997. In contrast, gains per acre on Luna were greatest in 1998 (136 lbs/acre), but gains in 1999 (64 lbs/acre) were similar to those during the shortened grazing period in 1997 (61 lbs/acre).

Management implication **-** Careful assessment of both the suitability of a planted species for the intended use and the hazard of undesired consequences, e.g., negative impacts on soil and native vegetation, should precede any pasture or rangeland planting. The levels of productivity and persistence of Rosana make this selected native cultivar of western wheatgrass a viable option when managers prefer using natives. However, the potential for greater animal gain in some environmental conditions (1998) confirms that Hycrest crested wheatgrass can be a useful forage plant for livestock production in the region. Based on the encroachment of invading species, persistence of Luna is marginal in the 13.4 in precipitation zone in the Northern Great Plains.

Future Direction: Additional replicated pastures (8 acres each) were seeded in autumn 1997 to Newhy, (a wheatgrass hybrid), Bozoisky Russian wildrye, Prairieland Altai wildrye, and Alkar tall wheatgrass. We have conducted a study during 2000-2002 comparing performance of L1 Hereford heifers grazing either seeded pastures (Hycrest, Rosana, and Luna) or native range during spring, all grazing native range during summer, and either grazing seeded pastures (Newhy, Bozoisky, Alkar, and Prairieland) or native range during autumn. We are just completing this study. Additional evaluation will be initiated with newly established species in spring 2004.

Relevant Publications:

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

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.

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 (*Pseudoroegneria 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., 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., 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. and E.E. Grings. 2000. To seed or not to seed... Montana Farmer Stockman 88:30-31.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2001. Livestock performance on seeded forages in the Northern Great Plains. Proc. West. Sec. Am. Soc. Anim. Sci. 52:326-328.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2002. Quality and persistence of cool-season forages in the Northern Great Plains. J. Range Manage. 55:482-487.

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

Heifer Production on Seeded Cool-Season Forages

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

Problem: Pastures seeded to cool-season grasses may be used to reduce grazing pressure on native rangelands. They may also provide high quality forage for livestock during early spring and autumn. Many varieties 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 varieties 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 varieties were compared in haying and grazing systems. Their ranking in the two systems differed. Thus, grazing trials are needed before release of varieties for commercial use. The goal of this project was to evaluate the performance of heifers grazing seeded forages versus native rangeland in the Northern Great Plains.

Procedures: Twice replicated 7.4-acre seeded pastures of Rosana western wheatgrass, Luna pubescent wheatgrass, Hycrest crested wheatgrass, and larger pastures of native rangeland were grazed during spring 2000 and 2001; native rangeland was grazed during summer; and twice replicated 8-acre seeded pastures of Alkar tall wheatgrass, Prairieland Altai wildrye, Bozoisky Russian wildrye, Newhy hybrid wheatgrass, and larger pastures of native rangeland were grazed during autumn.

Yearling Line 1 Hereford heifers (n = 7 per replication) grazed the spring pastures from 18 April to 30 May 2000 and 26 April to 23 May 2001; summer pastures from 30 May 2000 to 1 September 2000 and 23 May to 30 August 2001; and the autumn pastures from 1 September to 29 September 2000 for Bozoisky and Prairieland and 6 October for the other pastures and 30 August to 19 October 2001 for Bozoisky and 25 October for the other pastures. Heifers were weighed on and off each grazing event, and forage production/availability were assessed by harvesting standing crop immediately before and after each grazing event. Diet samples were obtained at the mid-point of each grazing event and analyzed for quality. Forage samples were dried, weighed, and analyzed for quality. Rainfall was monitored on site.

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

Findings: Average gain/head/day (lbs) in 2000 was greatest on Hycrest and Luna (2.1), intermediate on Rosana (1.6), and least on native rangeland (0.6); and gains in 2001 averaged 2.0 on seeded pastures versus 0.02 on native rangeland. When gains were compared for the period from early spring through late summer, no significant differences were detected among the pastures, and gains averaged 1.2 lbs/head/day. The increased gains on seeded pastures compared to native rangeland in spring did not have an effect on heifer pregnancy rates. During autumn, gains were significantly greater on Prairieland and Bozoisky (average 1.1 lbs/head/day) than on Alkar (0.5) or native rangeland (0.11), and gains on Newhy (0.74) were intermediate. Increased gains can occur on seeded pastures compared to native rangeland during spring grazing, but these gains may not be maintained through summer in the Northern Great Plains.

Future Direction: This study was repeated in 2002. Additional evaluations will be initiated with these and newly established species in spring 2004.

Relevant Publications:

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

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.

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 (*Pseudoroegneria spicata* [Pursh.] Love) hybrid, p. 897-898. *In*: M.J. Baker, J.R. Crush, and L. R. Humpreys (eds.) Proceedings XVII International Grassland Congress. Volume I. 8-21 February 1993. New Zealand and Queensland Australia.

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., 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. and E.E. Grings. 2000. To seed or not to seed... Montana Farmer Stockman 88:30-31.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2001. Livestock performance on seeded forages in the Northern Great Plains. Proc. West. Sec. Am. Soc. Anim. Sci. 52:326-328.

Haferkamp, M.R., E.E. Grings, R.K. Heitschmidt, and M.D. MacNeil. 2002. Quality and persistence of cool-season forages in the Northern Great Plains. J. Range Manage. 55:482-487.

Haferkamp, M.R., H. Horton, and K. Asay. 1997. Reseeding the range. Montana Farmer Stockman, 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? This research examined the impacts of grazing during and after drought on herbage growth dynamics and forage production.

Procedures: *Experiment 1* - This experiment 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 repeated on non-drought plots.

Experiment 2 - This experiment was conducted from 1998 through 2001 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.

Herbage growth dynamics and forage production were estimated, in both studies, by frequent harvesting of standing crop.

Findings: *Experiment 1* - The imposed 1994 drought reduced total forage production about 20% in 1994 and zero thereafter. The primary group of plants responsible for the 1994 decline was the cool-season perennial grasses, such as western wheatgrass and needle-and-thread (Figure 1). No declines in warm-season perennial grasses, annual grasses or forbs were noted during the 1994 drought. The only longer term affect of the drought on forage production was that annual grass production remained low in the 1994 drought plots in both 1995 and 1996. In 1995, annual grass production in the drought plots was 27 lbs/acre as compared to 203 lbs/acre in the non-drought plots. In 1996, annual grass production had increased in the drought plots to 123 lbs/acre as compared to 229 lbs/acre in the non-drought plots.

Surprisingly, grazing treatments did not appreciably affect total forage production during either the year of the drought (i.e., 1994) or the following growing seasons. Averaged across grazing and drought treatments, forage production was 2,050, 1,962, and 1,778 lbs/acre in 1994, 1995, and 1996, respectively. However, grazing during drought enhanced production of the warm-season perennial grasses during the drought.

Because precipitation in non-drought plots was below average during the imposed drought of 1994, the effects of the drought were probably less dramatic than if precipitation on the non-drought plots would have been near or above average. Still, the results of this study do reveal that neither summer drought nor periodic grazing during and after summer drought have much impact on annual forage production. In retrospect, this is not surprising in that these rangelands evolved under periodic summer drought conditions and frequent grazing by large ungulates.

Experiment 2 - In contrast to the results from Experiment 1, both drought and grazing had greater impacts on annual herbage production. However, as in Experiment 1, the year of the imposed drought (i.e., 1998) was also a "natural" drought which limited the measurable impacts of the drought. This is reflected by the fact that total forage

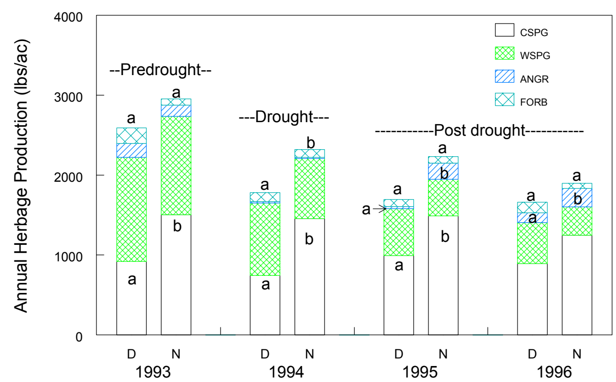


Figure 1. Annual herbage production (lbs/ac) by species group (CSPG = cool-season perennial grasses; WSPG = warm-season perennial grasses, ANGR = annual grasses; and FORB = forbs) from 1993 through 1996 in plots subjected to either summer drought (D) or normal precipitation (N) in 1994. Herbage amounts within-a-year with differing letters are significantly different at $P < 0.05$.

production in the non-drought plots was only 960 lbs/acre as compared to 2,081 lbs/acre in 1999 (Figure 2). Thus, the imposed drought of 1998 only reduced total forage production about 20% as compared to 1999 when the second year of spring drought reduced production about 40%.

The principal species group responsible for the 1998 decline was cool-season perennial grasses, whereas the 1999 decline was because both the cool-season perennial grass and forb production declined rather dramatically. However, the effects of the 1998 and 1999 droughts were not apparent in either 2000 or 2001 when averaged across grazing treatments.

In contrast to the results from Experiment 1, grazing treatments clearly impacted forage production during drought. In 1998, total forage production was greater with than without grazing largely because of increased cool-season perennial grass production (Figure 3). The effects of grazing on total forage production were less clear in 1999 with production in the ungrazed treatment (i.e., 1,683 lbs/acre) intermediate to the two grazed treatments (i.e., 1,423 and 1,844 lbs/acre). However, what was clear was that grazing enhanced forb production (i.e., 352 vs. 140 lbs/acre) and

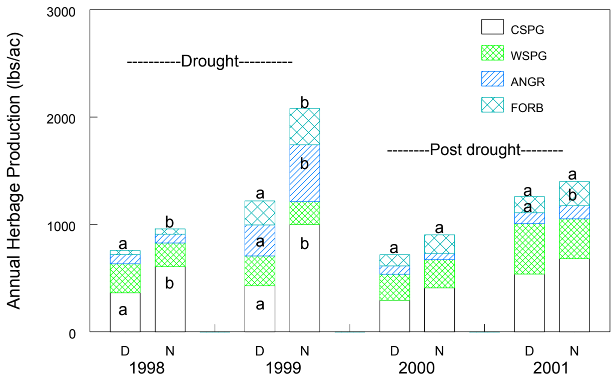


Figure 2. Annual herbage production (lbs/ac) by species group (CSPG = cool-season perennial grasses; WSPG = warm-season perennial grasses, ANGR = annual grasses; and FORB = forbs) from 1998 through 2001 in plots subjected to either spring drought (D) or normal precipitation (N) in 1998 and 1999. Herbage amounts within a year with differing letters are significantly different at P < 0.05.

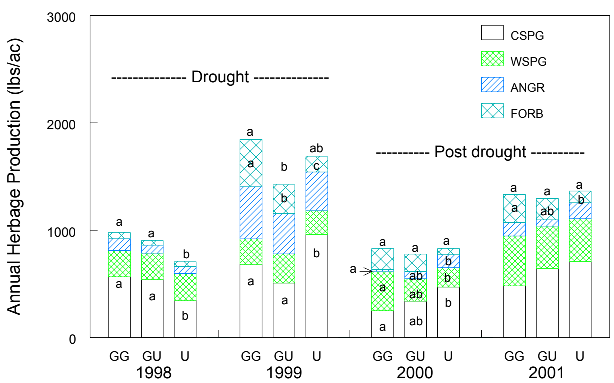


Figure 3. Annual herbage production (lbs/ac) averaged across drought treatments by species group (CSPG = cool-season perennial grasses; WSPG = warm-season perennial grasses, ANGR = annual grasses; and FORB = forbs) from 1998 through 2001 in plots subjected to either grazing during year of droughts (i.e., 1998 & 1999) and year after drought (GG), grazing only during years of drought (GU), or ungrazed during all years (U). Herbage amounts within a year with differing letters are significantly different at P < 0.05.

depressed cool-season perennial grass production (595 vs. 958 lbs/acre). This trend was carried over to 2000 but had completely disappeared by 2001.

The effects of grazing treatments on annual grasses were first noted in 2000 when production was substantially greater in the ungrazed than either the currently or previously grazed treatments. And the reverse was true for forb production in 2001 when production was least in the ungrazed treatment. The reasons for these two responses are unclear.

Based upon these results from this experiment and Experiment 1, it is obvious that the effects of a spring drought on Northern Great Plains forage production is much greater than a summer drought (see Figures 1 and 2).

Future Direction: A fundamental question that still needs answering is - Can the deleterious effects of a spring drought be overcome by timely summer precipitation? Even though we know the odds of getting substantial summer precipitation in this region are low, we still need to know what happens if we do get substantial precipitation. Thus, our next experiment is to simulate a spring drought and then follow it with above average summer precipitation (i.e., simulated precipitation by irrigation).

Relevant Publications:

Emmerich, W.E. and R.K. Heitschmidt. 2002. Drought and grazing: II. Effects on runoff and water quality. J. Range Manage. 55:229-234.

Eneboe, E.J., B.F. Sowell, R.K. Heitschmidt, M.G. Karl, and M.R. Haferkamp. 2002. Drought and grazing: IV. Blue grama and western wheatgrass. J. Range Manage. 55:197-203.

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

Hild, A.L., M.G. Karl, M.R. Haferkamp, and R.K. Heitschmidt. 2001. Drought and grazing: III. Root dynamics and germinable seed bank. J. Range Manage. 54:292-298.

Drought Management— Do You Have to Run Out of Forage Before You Manage?

R.K. Heitschmidt, K.D. Klement, and R.E. Kruse

Problem: A fundamental challenge in the range livestock industry is the timely implementation of drought management strategies. Although many producers have a drought management plan, implementation of said plan is often reactive rather than proactive. The reasons for this vary. But in our opinion, the fundamental reason ranchers delay implementing effective drought management plans is because they are eternal optimists relative to up-coming precipitation events. They know "precipitation is on its way" and this optimism is further bolstered by their belief that the next rain will significantly reduce, if not entirely eliminate, all drought related problems.

This problem is further compounded by our inability to accurately forecast "significant" precipitation events beyond a few hours or days. Still, there are certain drought driven realities that we tend to disregard or at least not fully appreciate. For example, it is well known that drought is an inherent trait of arid and semi-arid rangeland ecosystems for if that were not so, most would be forests. We also know that even in the best of times, we are within 2-3 weeks of being in a drought situation. We also know the odds of getting "significant" precipitation and the effects of said events on forage growth and productivity vary broadly over time.

Still, arid and semi-arid rangeland agriculturalists (i.e., ranchers) often fail to fully appreciate these realities, and the question becomes - why? Again, we would argue it is largely because they are necessarily eternal optimists when considering up-coming precipitation events for if this were not so, how could an arid or semi-arid grazier enjoy life? But perhaps it is also because rangeland agriculture researchers and extension specialists have also focused on the development of reactive rather than proactive drought management strategies. The objective of this paper is to outline a rather simple, yet we believe effective means for dealing with drought in a proactive manner.

Procedures: We analyzed a number of different data sets to address important questions relative to drought at Fort Keogh. We analyzed the last 106 years of monthly precipitation data from Miles City to determine the relationships among months and between monthly and total annual precipitation values. We also examined the relationships between monthly precipitation values and forage production at Fort Keogh using a simulation model. Finally, we examined the temporal dynamics of perennial grass production at LARRL using 14 data sets collected over the past 10 years.

Findings: We found no or at the best very weak relationships among monthly, bi-monthly, and seasonal amounts of precipitation. The question we were asking was - Can we predict future precipitation amounts based on current conditions? In other words, if precipitation in one month is above normal, average, or below normal, can we predict what precipitation is going to be at any time in the future? Our analyses of 106 years of precipitation data at Miles City says no.

We did find, however, that precipitation in 8 out of the 12 months of a year were positively correlated with total annual precipitation. The strongest relationship was between total spring precipitation (i.e., April + May + June) and annual precipitation wherein we could explain 62% of the variation in the 106 year data set. This relationship was not unexpected and it simply reinforces the idea that if precipitation in spring is below normal, more often than not total annual precipitation is also going to be below normal.

Using a simulation model, we found that 66% of the variation in annual forage production at Fort Keogh could be explained by April and May precipitation and 83% by April, May, and the previous year's October and November precipitation. In other words, if spring precipitation is below normal, annual forage production is most often also going to be below normal with fall precipitation the previous year modifying these effects slightly.

Using 14 frequent harvest data sets from Fort Keogh, we examined the relationships between total perennial grass production and time. From these analyses, we found that on the average 91% of perennial grass production is completed by July 1. More specifically, we found that a minimum of 79% will be grown by July 1 in 2 out of every 3 years and at least 65% will be grown in 19 out of 20 years.

Future Direction: Based on the above findings, we believe Northern Great Plains' ranchers can implement effective drought management strategies with considerable confidence by early summer because: 1) they know that total production is largely a function of springtime precipitation; and 2) most production is completed by July 1. So, by incorporating knowledge of the amount of springtime precipitation, relative to the long-term average, and visual assessment of July 1 perennial grass standing herbage, they can begin to adjust forage demand (i.e., stocking rates) long before they deplete their entire forage base.

Our long-term goal is to refine our understanding of these dynamics by incorporating additional knowledge gained from future simulated (i.e., rainout shelter) drought studies.

Relevant Publications:

Kruse, R.E. 2002. Beef cattle management decision relating to drought in the Northern Great Plains. M. S. Thesis, Montana State University. Bozeman, MT.

Effects of Season of Calving and Weaning Age on Cow and Calf Production Through Weaning

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

Problem: Decisions to optimize economic outcomes in cow/calf beef production systems are complicated because of the hundreds of variables that affect the economic and biological outcomes of the system. Also, these variables change dramatically over time (mainly seasonally and annually but at times the changes can be daily) and the optimal integration of decisions is almost always regional and even site specific due to unique aspects of regional ecosystems and individual ranches or production systems. Two of the most basic decisions that a cow/calf producer must deal with are 1) when should cows be bred and 2) when should the calves be weaned so that calving and weaning occur at the optimal times during the year. Research in other regions of the U. S. have shown season of calving affects amount and costs of inputs as well as production such as calf weaning weights and rebreeding percentages. There are also effects of age at weaning on cow/calf performance. This experiment is being conducted to better understand the economic and biological variables associated with season of calving and weaning age in a Northern Great Plains environment. The data reported here include only animal performance traits measured from calving to weaning from the first year of a three-year study.

Procedure: A herd of crossbred cows that were mainly crosses of Red Angus, Tarentaise, and Charolais, but also included some Hereford, Angus, Limousin, Piedmontese, and Simmental, were randomly assigned to one of three calving seasons (February, April, or June) and one of two weaning ages (early and late) within each season of calving. A summary of the design is shown in Table 1.

The April calving group was included to represent the normal calving season for this area, the February group was included to increase fall calf weights as is done currently in some systems, and the June calving group was included as an attempt to more closely align minimum nutrient requirements of the cow with the period of lowest quality grazed forage to decrease inputs from harvested feedstuffs. In this region, range forage is highest in quality and quantity in June and is lowest in January to March. Nutrient requirements of cows are greatest about 30 days after calving and then decrease to the lowest point after weaning. The result of these two seasonal fluctuations is that the earlier that peak lactation occurs before June, the more out of synchrony nutrient requirements of the cow are with available range forage.

Breeding was by natural service using the same battery of bulls (20 to 25 each year) in all three seasons. Bulls were in each herd for a total of 32 days, and Lutalyse® was injected 7 days after turning the bulls in to synchronize estrus and shorten the breeding season. All cows and heifers within each season of calving herd were bred in one pasture. Each season of calving herd was run completely independent (primarily on native or improved rangeland), and management decisions were made separately for each herd based on input needs for that herd. For example, the winter and spring calving herds were calved in lots and were moved to pasture after calving as forage became available, whereas the summer calving herd was calved on rangeland and were moved from one pasture to another as they calved. Winter supplementation strategy was tailored to the needs of individual herds.

Table 1. Experimental design

	Season of calving		
Item	Feb	April	June
Number calved	180	194	201
Number bred	258	257	266
Breeding season			
Begin	April 20	June 15	Aug 10
End	May 22	July 17	Sep 11
Calving season			
Begin	Jan 28	Mar 25	May 20
End	Feb 28	April 26	June 22
Weaning date (calf age)			
Early	Aug (6 mo)	Oct (6 mo)	Oct (4 mo)
Late	Oct (8 mo)	Dec (8 mo)	Dec (6 mo)

Early weaned steers were put in feedlots on a growing diet while early weaned heifers were held in feedlots for 10 to 25 days on a growing diet to adjust to weaning, and then half were turned out on improved pastures and half were left in the feedlot on a growing diet. Early weaned calves were reweighed on approximately the same day as late weaning so that both early and late weaned calves had comparable weights taken at both weanings. Calf weights were adjusted to a constant date (October 19) or to constant ages (140, 190, or 250 days) using weight gain from birth to weaning to make the adjustments. Cow data were also collected at both weanings but were not adjusted.

Findings: There were small but significant effects of season of calving on birth weight of calves, but these effects did not have any consistent pattern as calving season changed from early to late. Weaning weight of calves on a constant date was decreased as calving season became later. This decrease was partially caused by differences in chronological age, but also involved was the effect of season of calving on calf age-constant weights and calf gains. As calving season became later, age-constant weights decreased which was caused by a reduction in calf gains from birth to weaning. Calf gains from 1st to 2nd weaning (Weaning 2 - Weaning 1) also decreased as calving season became later with the largest decrease being in the June calvers.

Age at weaning had little effect on calf performance. The only significant effects observed were that, in the June season of calving, late weaned calves were heavier at 190 days and gained more from 1st to 2nd weaning than early-weaned calves.

Initial cow weight (Wean 1) was not affected by season of calving, but initial body condition score (**BCS**) decreased as season of calving became later. Cow weight change from 1st to 2nd weaning was less as season of calving became later and with late weaning. Cows lost condition from 1st to 2nd weaning. This decrease in BCS was not affected by season of calving, but it was more severe in late weaned than early weaned cows.

Rebreeding pregnancy rates were not affected by season of calving.

Future Direction: Data has been collected on 3 years of the calving and weaning systems and is being analyzed. Researchers at Montana State University will cooperate in conducting an economic analysis on the data. Heifers born and developed within the project have been retained within the three calving seasons to obtain follow-up information. Milk production and calf growth characteristics will be followed closely in these heifers in 2003 and 2004.

Relevant Publications:

Grings, E.E. and L. Schmidt. 2001. When the green grass grows. Montana Farmer-Stockman. 11:16-17.

Grings. E.E., R.E. Short, M. Blummel, M.D. MacNeil, and R.A. Bellows. 2001. Prepartum supplementation with protein or fat and protein for grazing cows in three seasons of calving. Proc. West. Sec. Amer. Soc. Anim. Sci. 52:501-504.

Grings, E.E., R.E. Short, T.W. Geary, and M.D. MacNeil. 2002. Heifer development within three seasons of calving. Proc. West. Sec. Amer. Soc. Anim. Sci. 53:261-264.

Grings, E.E., R.E. Short, and R.K Heitschmidt. 2000. Effects of season of calving and weaning age on cow and calf production through weaning. Proc. West. Sec. Amer. Soc. Anim. Sci. 51:125-127.

Phillips, W.A., S.W. Coleman, E.E. Grings, D.G. Riley, C.C. Chase, R.E. Short, H.S. Mayeux, and R.K. Heitschmidt. 2002. Performance of steer calves reared in temperate or sub-tropic environments and used as stocker calves on winter wheat pasture. USDA-ARS Grazinglands Research Laboratory Field Day Report. Pp. 44-45.

Phillips, W.A., E.E. Grings, S.W. Coleman, R.E. Short, D. G. Riley, C.C. Chase, H.S. Mayeux, and R.K. Heitschmidt. 2002. Winter and spring performance of steer calves reared in temperate or sub-tropic environments and used as stocker calves on winter wheat pasture in Oklahoma. J. Anim. Sci. 80 (Suppl. 1):147. Abstract.

Phillips, W.A., E.E. Grings, J.W. Holloway, R.E. Short, R. Warrington, H.S. Mayeux, and R.K. Heitschmidt. 2002. Increasing the performance of stocker calves on winter wheat pasture. USDA-ARS Grazinglands Research Laboratory Field Day Report. Pp. 49-50.

Table 2. Effects of season of calving and calf weaning age on cow and calf traits (mean ± S.E.) measured from birth to weaning

Trait	Date, age (d), or weaning[a]	Wean group[a]	Season of calving: Feb	April	June
Birth wt, lbs	—	—	81 ± 0.9[b,d]	78 ± 0.9[b]	83 ± 1.1[d]
Calf wean	Oct 19	—	598 ± 4.6[a]	495 ± 4.2[b]	356 ± 5.3[c]
wt, lbs	140	Early	—	—	352 ± 6.6
		Late	—	—	359 ± 6.8
	190	Early	502 ± 5.5[b]	471 ± 5.3[c]	409 ± 7.7[e]
		Late	493 ± 5.7[b]	473 ± 5.3[c]	431 ± 7.9[d]
	250	Early	601 ± 6.6[b]	559 ± 6.2[c]	—
		Late	590 ± 6.8[b]	568 ± 6.2[c]	—
Calf gain, lbs	Wean 2 - Wean 1	Early	99 ± 2.4[b]	88 ± 2.4[c]	57 ± 2.9[e]
		Late	97 ± 2.4[b]	92 ± 2.4[b,c]	73 ± 3.1[d]
Cow wt, lbs	Wean 1	Early	1,142 ± 14.7	1,126 ± 13.9	1,096 ± 17.4
		Late	1,135 ± 15.0	1,131 ± 13.9	1,122 ± 17.4
Cow wt Change, lbs	Wean 2 - Wean 1	Early	85.1 ± 6.4[b]	32.3 ± 6.2[c]	12.8 ± 8.1[c]
		Late	23.5 ± 5.9[c]	-12.1 ± 5.5[d]	-34.5 ± 7.0[e]
Cow CS	Wean 1	Early	5.4 ± 0.09[b]	5.1 ± 0.08[c]	4.8 ± 10[d]
		Late	5.4 ± 0.09[b]	5.1 ± 0.08[c]	5.0 ± 10[c,d]
CS Change	Wean 2 - Wean 1	Early	-0.04 ± 0.09[b]	-0.03 ± 0.09[b]	-0.30 ± 12[b,c]
		Late	-0.54 ± 0.09[c,d]	-0.51 ± 0.08[c,d]	-0.64 ± 0.10[d]
Preg, %	—	—	86.3 ± 2.4	85.2 ± 2.3	87.1 ± 2.7

[a]Wean 1 and early weaning were in August for February calvers and in October for April and June calvers and Wean 2 and late weaning were in October for February calvers and December for April and June calvers.
[b,c,d,e]Means with different superscripts within trait and age are different ($P < 0.05$).

Performance of Steer Calves Born in the Northern Great Plains in Three Seasons of Calving and Used as Stocker Cattle on Winter Wheat Pasture in the Southern Great Plains

E.E. Grings, W.A. Phillips, R.E. Short,
H.S. Mayeux and R.K. Heitschmidt

Problem: Each fall millions of stocker calves are brought into the southern Great Plains region to graze winter wheat before entering a feedlot for finishing. Rather than owning the calves, producers may decide to act as subcontractors who are paid by the amount of gain accumulated by each calf. The value of this system may vary by weight and gain potential of calves, as affected by age and prior nutritional status of calves.

Procedure: Fifty-three steer calves from USDA-ARS, Fort Keogh LARRL were born in February, April, or June and weaned in October, creating calves of different ages and body weights. Following a preconditioning period, steers were shipped 1,140 miles to the USDA-ARS, Grazinglands Research Laboratory, El Reno, OK, on November 14, 2000. Because winter wheat was limited due to drought conditions, all steers were placed in a dormant warm-season grass pasture. The steers had ad libitum access to hay and a mixed diet in a self-feeder. The mixed diet was formulated to have a crude protein content of 14% and a TDN concentration of 79%. A buffer was added to the mixed diet to prevent acidosis and an ionophore was added to increase performance. The combination of mixed diet and hay was calculated to result in an average daily gain **(ADG)** of 1.7 lbs, which would be similar to the anticipated ADG on wheat pasture. In April, steers were placed on winter wheat pasture for a 63-day grazing period.

Findings: Performance of steers weaned in October at 4, 6, or 8 months of age are presented in Table 1. The amount of winter wheat gain decreased as the initial body weight and age at weaning decreased. During the spring grazing period, the younger, lighter calves gained weight more rapidly than the older heavier calves. By the beginning of the spring grazing period, the older February born calves weighed over 800 lbs, while the younger June calves weighed just over 640 lbs. The June calves probably had to expend less energy for maintenance, so they could gain more rapidly. Because the value of gain is greater for lighter calves than for heavier calves, owning the June-born calves would probably be more profitable than being paid for gain as a subcontractor. The opposite would be true for the February-born calves. Because the February-born calves were heavier at arrival and gained more weight during the winter than the younger calves, being paid for gain would be more economical.

Table 1. Gain of steer calves born in February, April, or June and weaned in October

Month of birth	Age at weaning	Initial body weight	Winter weight gain	Spring weight gain
	Months	----------------------	lbs	----------------------
February	8	538	307	32
April	6	433	282	47
June	4	386	272	56

Future Directions: Steers from the three seasons of calving (late winter, early spring, late spring) were shipped to Oklahoma for three (2000 to 2002) years. Steers were placed on varied management strategies through slaughter. Carcass data has been collected on these steers and on steers raised to slaughter at LARRL allowing for additional comparisons to be made.

Relevant Publications:

Phillips, W.A., S.W. Coleman, E.E. Grings, D.G. Riley, C. C. Chase, R.E. Short, H.S. Mayeux, and R.K. Heitschmidt. 2002. Performance of steer calves reared in temperate or sub-tropic environments and used as stocker calves on winter wheat pasture. USDA-ARS Grazinglands Research Laboratory Field Day Report. Pp 44-45.

Phillips, W.A., E.E. Grings, S.W. Coleman, R.E. Short, D. G. Riley, C.C. Chase, H.S. Mayeux, and R.K. Heitschmidt. 2002. Winter and spring performance of steer calves reared in temperate or sub-tropic environments and used as stocker calves on winter wheat pasture in Oklahoma. J. Anim. Sci. 80 (Suppl. 1):147. Abstract.

Phillips, W.A., E.E. Grings, J.W. Holloway, R.E. Short, R. Warrington, H.S. Mayeux, and R.K. Heitschmidt. 2002. Increasing the performance of stocker calves on winter wheat pasture. USDA-ARS Grazinglands Research Laboratory Field Day Report. Pp 49-50.

C. Enhancing Female Fertility

Reproductive Problems Take a $14.90/Cow Bite.
Reproductive problems take an average bite of $14.90/beef cow/year, says a collaborative study between USDA (Dr. Bob Bellows) *and Purina Mills* (Dave Bellows) *researchers. Summarizing state and national reports the researchers determined that losses from reproductive problems are six times greater than from respiratory diseases, with infertility and dystocia accounting for more than 80% of the losses.*

Female infertility is the biggest culprit, the researchers say, accounting for 49.8% of reproductive problems. That's followed by dystocia at 37%, abortions and stillbirths at 12.8%, metritis and pyometra at 0.3% and retained placenta at 0.2%. The researchers say the results indicate that focusing on strategies to improve the probability of conception, minimize dystocia and produce a healthy calf that survives beyond the first 24 hours of birth must continue to receive high priority in beef management. Quote from Joe Roybal (Editor, BEEF Magazine) in Cow-Calf Weekly e-newsletter.

Fertility in beef cattle is regulated by many cellular and hormonal interactions 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 and improve reproductive efficiency. 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.



Profitability of Estrous Synchronization with Natural Service

T.W. Geary

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 have calved at least 40 days previously 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.

Procedures: Nine hundred and fifteen beef cows in four herds located in Montana and Colorado were used to evaluate productivity and reproductive performance response to estrous synchronization and natural service. Herds ranged in size from 149 to 285 head. Approximately one-half of the cows at each location received the synchronization treatment (Select Synch: Figure 1) and one-half of the cows received no treatment (Control). Cows were exposed for 50 or 60 days to bulls that satisfactorily passed a breeding soundness examination, and a bull to cow ratio between 1:17 to 1:30. At the Colorado location, treatments were applied to cows in separate pastures, and thus cows were exposed to different bulls. At each of the Montana locations, both treatments were applied to cows within the same breeding pasture, so cows were exposed to the same bulls. The Select Synch protocol included administration of gonadotropin releasing hormone **(GnRH)** followed 1 week later by administration of prostaglandin **(PGF)**. Beginning 2 days before administration of PGF, cows were exposed to bulls. Measurements included pregnancy rate, calving date, and subsequent rebreeding performance of cows, and percent calf crop weaned, weaning weight, and value at weaning.

Findings: Across locations, pregnancy rates were 5% higher for cows receiving the synchronization treatment

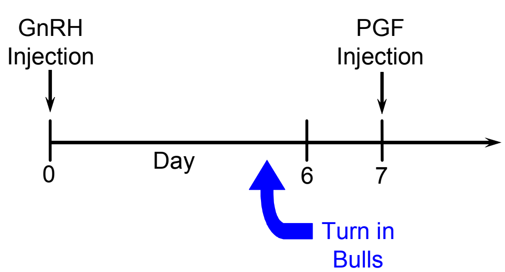


Figure 1. Select Synch protocol with natural service.

(Table 1) and ranged from +21% to -5% pregnant compared to controls. Average calving date was just 1 day earlier for synchronized cows and ranged from -2 to 0 days earlier than control cows. Calving season, however, was 11 days shorter for cows that were synchronized. More synchronized cows calved during the first 21 days of the calving season, while percentage of cows calving within the first 42 days did not differ between treatments.

Table 1. Performance measurements of synchronized (Select Synch protocol) and control cows bred by natural service at four locations in Colorado and Montana

Measurement	Synchronized	Control	Difference
No. Cows	458 cows	457 cows	1 cow
Pregnancy rate	89%	84%	5%
Average calving date	March 3	March 4	1 day
Percent calved 1st 21 days	61%	51%	10%
Percent calved 2nd 21 days	34%	44%	-10%
Percent calved 3rd 21 days	5%	6%	-1%
Calving season length	54 days	65 days	11 days
Percent calf crop weaned	84%	77%	7%
Montana herds	382 cows	384 cows	-2 cows
Average weaning weight	461 lbs	453 lbs	8 lbs
Actual lbs weaned	177,485	162,293	15,192
Weaning Income (@ $80.00/cwt)	$141,988	$129,834	$12,154
Synchronization costs (@ $5.50/cow)	-$2,101	$0	-$2101
Net profit	$139,887	$129,834	$10,053
Subsequent breeding Pregnancy rate	88%	92%	-4%

Calves were not individually identified at birth in the Colorado herd, so measuring the effects of synchronization on weaning weight were not possible in that herd. Among Montana herds, 94% of synchronized and 92% of control cows that were diagnosed pregnant actually weaned calves. Thus, percent calf crop weaned (percentage of cows weaning a calf that were exposed to breeding the previous year) was 77% for control cows and 84% for synchronized cows among Montana herds. The Montana cows whose estrous cycles were synchronized at the beginning of the breeding season weaned 15,192 pounds more than control cows. Assuming an average price of $0.80 per pound, synchronizing cows before the start of the breeding season increased income by $12,154 across the three Montana herds. Synchronization drugs ($5.50 per cow) represented a cost of $2,101 yielding a return of $10,053 (or $26.32 per cow exposed). The income reported in Table 1 assumes sale of all calves and does not consider the fact that a producer would need to retain 7% more heifers for replacements without synchronization. Developing replacement heifers is a costly endeavor for most operations since the average cow does not pay for herself until she has weaned four consecutive calves. The pregnancy rate of cows exposed during the breeding season after synchronization (2nd year) was not improved among previously synchronized cows (88%) compared to control cows (92%). Failure to realize an improvement in pregnancy rate during the breeding season one year later may be due to the lack of difference in average birth date and sale of pairs that calved late during year 1.

Future Direction: Continued research is warranted in this area to evaluate the appropriate bull to female ratio and optimal breeding pasture size. We are evaluating our ability to lead this type of research in future years.

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

T.W. Geary

Problem: Less than 6% of the beef cattle in the United States are bred by artificial insemination **(AI)** each year. The primary reason that so few cattle are artificially inseminated is due to the time and labor involved with detection of estrus. Estrous synchronization decreases the amount of time required for detection of estrus and facilitates the use of AI. To a producer, a good synchronization protocol must be cheap, easy to administer, effective on the majority of the cows in a herd (must induce estrous cycles), and results in high pregnancy rates.

Several estrous and ovulation synchronization protocols are available and no single protocol is the best one for all situations. The objectives of these studies were: to decrease the cost of the CO-Synch estrous/ovulation synchronization protocol for use in beef cows (study 1) by evaluating efficacy of reduced dosage of gonadotropin releasing hormone (**GnRH**), and improve the pregnancy rate following AI with the addition of bovine somatotropin (**bST**; study 2). Both studies were conducted in collaboration with Dr. Jack Whittier at Colorado State University.

Procedures: *Study 1.* Primiparous (n = 76) and multiparous (n = 328) Angus cows from one location with an average body condition score **(BCS)** of 5.5 and postpartum interval **(PPI)** to day 0 (1st GnRH injection) of the synchronization protocol of 68 days were blocked by age and postpartum interval and were randomly assigned to one of four treatment groups. Blood samples, that were taken before initiation of the synchronization protocol, determine the number of anestrous cows in each treatment. The CO-Synch protocol includes a 100 µg intramuscular injection of GnRH followed by a 25 mg injection of prostaglandin (**PGF**) 7 days later, and another 100 µg injection of GnRH on day 9, at which time cows are also mass inseminated. The 100 µg dosage of GnRH used in estrous synchronization protocols is based on product manufacture recommendations for the treatment of ovarian cysts. However, other studies have demonstrated that an intramuscular of 50 µg was as effective as 100 or 250 µg of GnRH to treat ovarian cysts. Each dosage elevated plasma luteinize hormone **(LH)** concentration within 30 minutes following injection and LH remained elevated for 4 hours. Based on this study, a half dose of GnRH may be as effective at inducing a new follicular wave and inducing a preovulatory surge of LH at the time of mass mating as the more traditional dose. In the experimental protocol, cows were randomly assigned to receive 50 µg (1 mL volume) or 100 µg (2 mL volume) GnRH at either the first or second injection, or both. The result was four separate treatment groups: 50:50, 50:100, 100:50, and 100:100 µg GnRH.

Beginning on day 6 after the first GnRH injection, cows were observed for standing estrus, and if they were observed to be in heat, received AI approximately 10 to 12 hours later. Calves were removed for a 48 hour period on day 7 and were put back with the cows immediately after breeding on day 9. Clean-up bulls were turned in with the cows 14 days following AI. Sixty-eight days after mass mating, all cows were diagnosed for pregnancy via transrectal ultrasonography to determine the number of females that conceived to AI.

Study 2. Objectives were to examine effects of exogenous bST on pregnancy rates in conjunction with two separate estrous synchronization protocols: CO-Synch and Select Synch. In the CO-Synch trial, lactating beef cows (n = 690) from three locations were administered 100 µg of GnRH on day 0, followed 7 days later by 25 mg of PGF, and on day 9 cows received another 100 µg of GnRH and were inseminated. Cows were assigned to the following treatments: 500 mg of bST administered at the 1st GnRH injection, bST with PGF, bST with the 2nd GnRH injection, and no bST (Control). In the second trial, lactating beef cows (n = 581) were synchronized using the Select Synch protocol. On day 0, cows were administered 100 µg of GnRH, followed 7 days later by 25 mg of PGF combined with heat detection and AI on days 6 through 11. Cows were assigned to the following treatments: 500 mg of bST administered at the time of GnRH administration, bST with PGF, and no bST (Control). Cows were examined for pregnancy at approximately 60 days post AI.

Findings: *Study 1.* Eighteen cows exhibited estrus between day 6 through 9 and were bred before mass mating the remainder of the cows. This herd had a high percentage (65.1%) of anestrous cows at the initiation of synchronization, which were similarly distributed between treatments. Pregnancy rates for cows treated with either a 50 or 100 µg dose of GnRH at either the first and/or second injection in the CO-Synch protocol were not different (Figure 1).

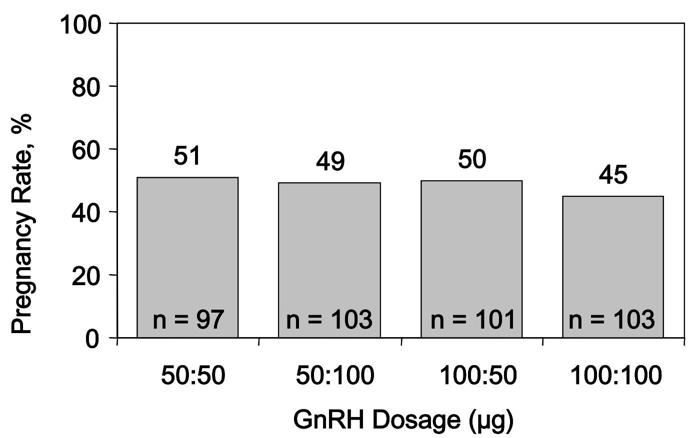


Figure 1. Pregnancy rates following fixed time AI of cows receiving half dose (50) or full dose (100) GnRH at the 1st and/or 2nd GnRH injection using the CO-Synch protocol.

Study 2. Pregnancy rates for CO-Synch treated cows receiving bST at 1st GnRH, PGF, 2nd GnRH, or control cows were 30.0%, 26.9%, 33.1%, and 27.1%, respectively, were not different. Bovine somatotropin had no effect on pregnancy rates in the CO-Synch ovulation synchronization protocol. In the Select Synch trial, estrous response was higher for cows receiving bST at the time of GnRH injection

(70%), but not different between cows receiving bST at the time of PGF (58%) and control cows (59%). Pregnancy rates were higher for cows receiving bST with GnRH (64%) and control cows (60%) than for the cows receiving bST in conjunction with PGF (35%). Pregnancy rates were not different between cows receiving bST with GnRH and controls. Based on this trial, bST does not have a beneficial effect on pregnancy rates, but does have a deleterious effect when administered at the time of PGF.

Future Direction: No future studies are planned in this area.

Relevant Publications:

Geary, T.W., J.C. Whittier, D.M. Hallford, and M.D. MacNeil. 2001. Calf removal improves conception rates to the Ovsynch and CO-Synch protocols. J. Anim. Sci. 79:1-4.

Use of Timed Artificial Insemination With Gonadotropin-Releasing Hormone/Prostaglandin Estrous and Ovulation Synchronization Protocols For Use in Beef Cows

T.W. Geary

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. 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 availability 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 cattle for signs of estrus 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 gonadotropin-releasing hormone/prostaglandin (**GnRH/PGF**) (Select Synch) protocol evolved from the Ovsynch protocol in dairy cows and has been used to synchronize estrus in beef cows (Figure 1). The CO-Synch protocol also evolved from the Ovsynch protocol and includes a second injection of GnRH with fixed time AI 48 hours after the PGF injection. Published pregnancy rates to a strictly timed AI protocol (CO-Synch) ranged from 49% to 63% depending on whether or not 48-hour calf removal was utilized. The Select Synch and CO-Synch protocols both result in about 9% of cows exhibiting estrus within 30 hours before the PGF injection. Cows that exhibit estrus within 24 hours of the PGF injection have little chance of conceiving to the CO-Synch protocol. In addition, there is added risk and cost involved by using strictly a fixed time AI protocol. Many producers have adopted a hybrid system that includes breeding cows following estrus for 48 to 72 hours after PGF and using fixed time AI in conjunction with a second injection of GnRH only for those cows not observed in estrus. The most appropriate time for a second GnRH injection and timed AI has been debated. The mean interval from PGF to estrus with the Select Synch protocol is approximately 70 hours. The objective of this study was to determine whether addition of a second GnRH injection at 72 hours would improve pregnancy response to a timed insemination in cows that had not yet been observed in estrus.

Procedures: This study was conducted on two separate herds of mature ($\geq$ 4 year old) crossbred cows (n = 994) at the Rex Ranch in Central Nebraska during the 1997 and 1999 breeding seasons. Cows in both herds were genetically similar and managed similarly between years. Cows (n = 257) in herd 1 (1997) had a mean body condition score (**BCS**) of 5.5 (1 to 9 scale), and a postpartum interval (**PPI**) to AI of 69 days. Cows (n = 737) in herd 2 (1999) had a BCS of 4.9 and PPI of 77 days. Cows received the Select Synch protocol to synchronize estrus. Cows were observed for signs of estrus for approximately 2 hours each morning and evening from the time of PGF injection until 72 hours later. Cows that were observed in estrus received AI approximately 12 hours later (**EAI**). Cows not detected in estrus by 72 hours after PGF were divided into two groups and time inseminated at 72 hours with (**TAI+GnRH**) or without (**TAI**) a second injection of GnRH (100 μ). The same sires and technicians were not used each year, but were randomized across treatments. Cleanup bulls were placed with cows 7 to 10 days (1997 and 1999, respectively) following timed AI for the remainder of the 60-day breeding season. Cows were diagnosed for pregnancy by ultrasound approximately 65 days after AI.

Findings: The AI pregnancy rates obtained from combining data of cows bred following estrus with those time inseminated at 72 hours after PGF with or without a second GnRH injection is illustrated in Figure 2. There was no benefit to giving a second GnRH injection to cows that were time inseminated at 72 hours after PGF. Cows in this study were not observed for estrus before the PGF injection. Because approximately 9% of cows receiving the Select Synch protocol exhibit estrus before the PGF injection,

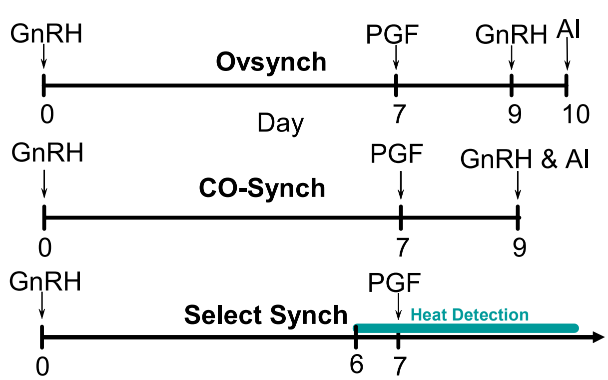


Figure 1. Illustration of the Ovsynch, CO-Synch, and Select Synch protocols for synchronizing estrus/ovulation.

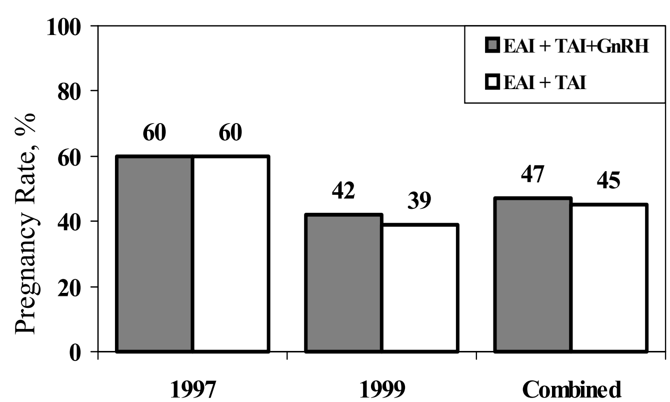


Figure 2. Pregnancy rates of cows bred following estrus (EAI) with non-responding cows bred at 72 hours after PGF with (TAI+GnRH) or without (TAI) a second GnRH injection.

one might expect a 5% increase in overall pregnancy rates by observing cows for an early estrus and breeding them at the appropriate time.

The variation in response that was observed between years in this study represents a concern for producers that might adopt this protocol for their cowherd. We have noticed large variations in the interval from PGF injection to estrus between herds in other studies when the Select Synch protocol was used. Some of the variables that affect this time interval may include the percentage of cows that are anestrus, the percentage of cows that have two or three waves of follicular growth during an estrous cycle, plane of nutrition, and environmental conditions. The 72-hour estrous response was 51% and 27% for cows during 1997 and 1999, respectively. Identifiable differences between the herds used in 1997 and 1999 are shown in Table 1. The large difference in 72-hour estrous response 51% versus 27% for 1997 and 1999, respectively, is difficult to explain since BCS and PPI of cows were similar between years. The Select Synch protocol can induce estrous cycles in anestrous cows and may be dependent upon several factors, including how close a cow is to resuming estrous cyclicity on her own. Estrous detection efficiency (ability to detect 100% of cows that were in estrus) may have been lower in 1999 due to inherent problems with detecting estrus in a larger herd. The accuracy of estrous detection (presenting only estrual cows for AI) does not appear to have been compromised since the fertility of cows detected in estrus did not differ between years. Pooled across years, pregnancy rate of EAI cows (60%) was greater than pregnancy rate of TAI+GnRH (33%) or TAI (27%) cows, but pregnancy rate did not differ between TAI+GnRH and TAI cows. There was an interaction between year and treatment. During 1997, pregnancy rates were not different between EAI (61%), TAI+GnRH (54%), and TAI (55%) cows. During 1999, pregnancy rates were higher for EAI (59%) cows but did not differ between TAI+GnRH (30%) and TAI (23%) cows. The average interval to estrus with the Select Synch protocol is 70 hours, and an endogenous GnRH surge occurs 3 to 6 hours after the onset of estrus, therefore, the majority of the non-responding cows probably experienced an endogenous GnRH surge, and thus, did not benefit from the second GnRH injection.

Table 1. Characteristics of cattle bred during the 1997 or 1999 breeding season

Characteristic	1997	1999	1999-1997
No. head	332[a]	737	405
Mean BCS	5.5	4.9	-.6
Mean PPI, d	69	77	8
EAI pregnancy rate, %	61	59	2
72 h estrous response, %	51	27	-24

[a]Seventy-five cows that were not detected in estrus were time inseminated at 84 hours and were not included in the analyses other than for determining estrous response.

Moving the time of insemination and second GnRH injection of the CO-Synch protocol which includes the first two injections of the Select Synch protocol and timed insemination with a second GnRH injection at 48 hours after PGF to 64 hours after PGF resulted in higher pregnancy rates in some herds and lower pregnancy rates in other herds (unpublished data). We interpret this to mean that in some herds, we have lost the opportunity to induce a fertile ovulation with a second GnRH injection by moving the GnRH injection later than 48 hours after PGF injection. When estrous detection efficiency is high during the time period from -30 to 72 hours after PGF (0 hours), breeding by estrus until 72 hours coupled with timed AI at 72 hours should result in high pregnancy rates. However, when estrous detection efficiency is low or in herds that have not had a high estrous response (> 50%) by 72 hours after PGF, it might be more economical to continue to observe cows and AI following observation of estrus for an additional 2 days rather than mass inseminating cows. We conclude that incorporating a timed AI at 72 hours after PGF for cows synchronized with the Select Synch protocol may be feasible if the 72-hour estrous response is high, but caution against timed AI at 72 hours in herds when the 72-hour estrous response is low. Also, addition of a second injection of GnRH at 72 hours is not necessary.

Future Direction: No future research is planned in this area.

Relevant Publications:

Geary, T.W., E.R. Downing, J.C. Bruemmer, and J.C. Whittier. 2000. Ovarian and estrous response of suckled beef cows to the Select Synch estrous synchronization protocol. Prof. Anim. Sci. 16:1-5.

Geary, T.W., and J.C. Whittier. 1998. Effect of a timed insemination following synchronization of ovulation using the Ovsynch or CO-Synch protocol in beef cows. Prof. Anim. Sci. 14:217-220.

Improvements in Estrous Synchronization Among Beef Heifers

T.W. Geary and R.N. Funston

Problem: The melengestrol acetate/prostaglandin (**MGA/PGF**) protocol has long been considered the industry standard for synchronizing estrus in beef heifers. The traditional MGA/PGF protocol includes feeding MGA to each heifer at a rate of 0.5 mg per day for 14 days followed by administration of PGF 17 days after the final day of feeding MGA. While it has served as an industry standard for beef heifers, it is not widely used for beef cows because of its length (31 days) and increased incidence in twinning. This article summarizes several studies over the last 3 years that tried to improve upon the MGA/PGF protocol in beef heifers.

Procedures: *Study 1.* The objective of this study was to determine if producers could realize similar pregnancy rates with a single timed insemination of beef heifers synchronized with the MGA/PGF protocol compared to am/pm artificial insemination (**AI**) by estrous detection for 5 days following synchronization. Beef heifers (n = 604) from three locations received the MGA/PGF protocol for synchronization of estrus (Figure 1). Heifers were observed for signs of estrus for 5 days following the PGF injection. One half of the heifers at each location received artificial insemination approximately 12 hours after standing estrus (**EAI**) and the other half were inseminated at 72 hours following the PGF injection (**TAI**). Either even or odd numbered heifers received the EAI or TAI treatments at each location. Pregnancy rates were determined by ultrasound approximately 40 days after the timed insemination to evaluate the need for heat detection.

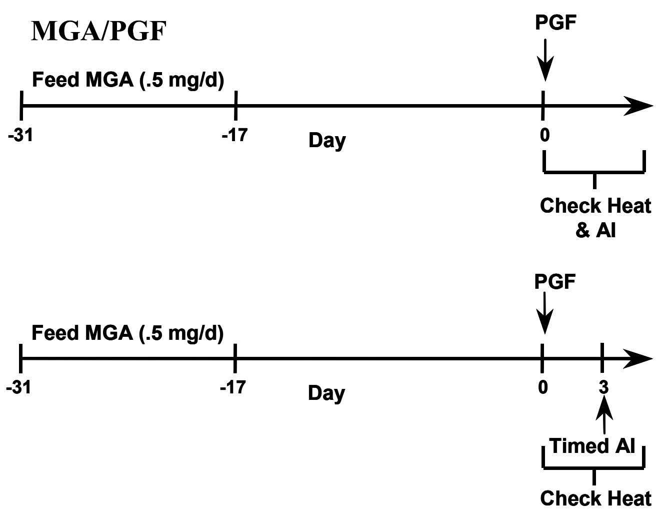


Figure 1. Illustration of the MGA/PGF protocol used to synchronize estrus in study 1 comparing artificial insemination (AI) approximately 12 hours after detection of estrus (top panel) or timed AI at 72 hours after PGF (bottom panel).

Study 2. The objective of this study was to determine whether addition of MGA for 7 days before the start of the Select Synch protocol would improve estrous synchronization, conception, and pregnancy rates among beef heifers. Beef heifers (n = 796) received either the MGA/PGF protocol (n = 394; Figure 1) or the MGA/Select Synch protocol (n = 402; Figure 2) for synchronization of estrus. Heifers that exhibited estrus were artificially inseminated approximately 12 hours later. Cleanup bulls were placed with heifers 7 days after the last artificial insemination (**AI**). Pregnancy was determined by ultrasound approximately (14/19 d) 42 days following synchronization.

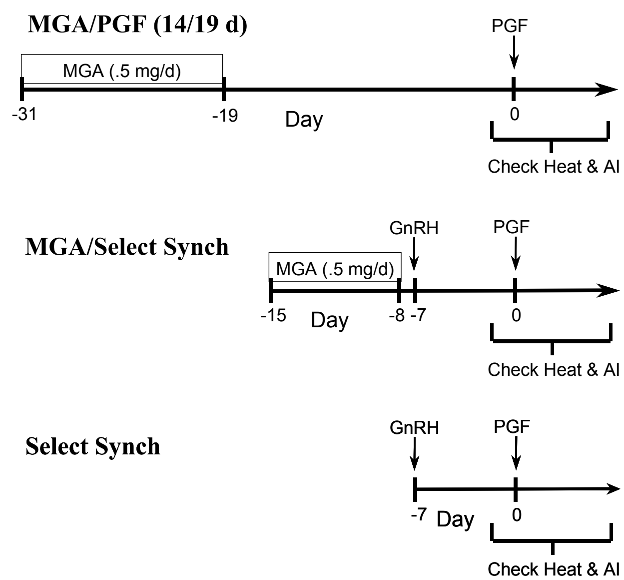


Figure 2. Illustration of the MGA/PGF, MGA/Select Synch, and Select Synch protocols.

Study 3. The objective of this study was to evaluate synchronization, conception, and pregnancy rates of heifers synchronized with MGA/PGF, Select Synch, or Select Synch preceded by MGA (MGA/Select Synch) to identify the optimal synchronization system for heifers (Figure 2). Recent discoveries that lead to evaluation of this protocol included reports of improved synchronization, conception, and pregnancy rates among heifers synchronized with the traditional MGA/PGF protocol by extending the interval from last feeding of MGA to PGF from 17 to 19 days. Approximately 210 heifers received each of the 3 protocols illustrated by Figure 2. All heifers received PGF on the same day. Heifers were observed for estrus continuously during daylight from 4 days before through 5 days after PGF and bred by AI approximately 12 hours after onset of estrus. Pregnancy status was determined by ultrasound approximately 50 days after AI.

Findings: *Study 1.* Conception rates, but not pregnancy rates of MGA/PGF synchronized heifers bred following a detected estrus were higher than conception rates of heifers bred to a fixed time AI 72 hours after PGF (Figure 3). Conception rate represents the number of heifers pregnant divided by the number of heifers inseminated, whereas pregnancy rate represents the number of pregnant heifers divided by the total number of heifers exposed to the syn-

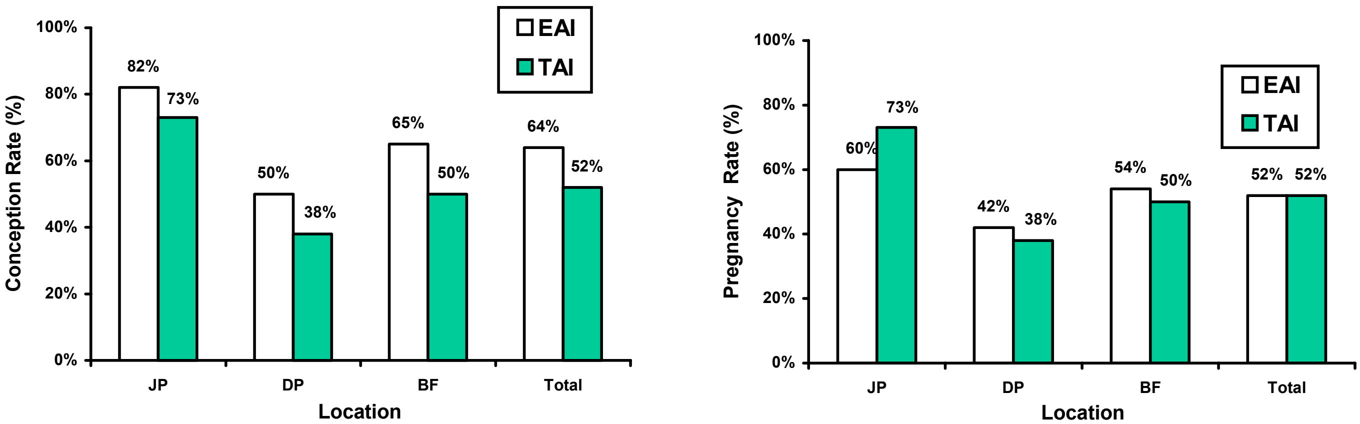


Figure 3. Conception and pregnancy rates of heifers synchronized with the MGA/PGF protocol and inseminated following detected estrus (EAI) or at a fixed time (TAI; 72 hours after PGF).

chronization treatment. Thus, when the costs of heat detection and repeated scheduling of technician service is more expensive than the cost of semen, producers might find it more economical to schedule a fixed time AI for all heifers in the program.

Study 2. Estrous response tended to be higher for MGA/Select Synch (82%) when compared to MGA/PGF heifers (77%). Conception and pregnancy rates were similar between treatments (Figure 4). Mean estrous response (hours) was earlier for the MGA/Select Synch versus MGA/PGF treatment, 56 versus 61 hours post-PGF treatment, respectively. The MGA/Select Synch protocol may provide an acceptable alternative for producers to synchronize es-

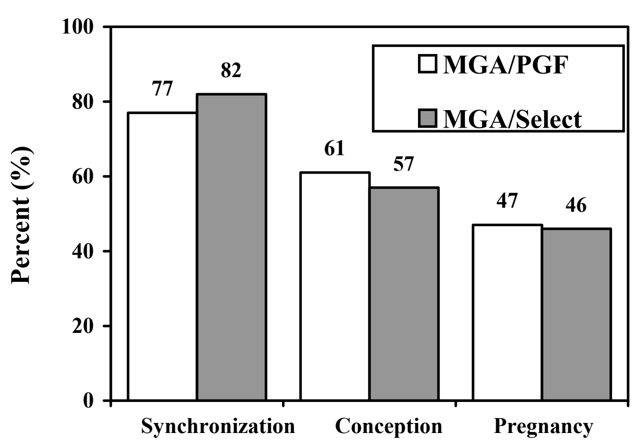


Figure 4. Synchronization, conception, and pregnancy rates of heifers receiving the traditional MGA/PGF or MGA/Select Synch synchronization treatment.

trus among heifers that require a shorter synchronization protocol.

Study 3. More heifers were observed in estrus before PGF injection in both the Select Synch (20%) and MGA/Select Synch (24%) groups than the MGA/PGF (4%) group. Pregnancy rates for heifers in estrus early were higher for both Select Synch (55%) and MGA/Select Synch (63%) compared to MGA/PGF heifers (18%). Synchronization rate (after PGF) was higher for MGA/PGF heifers (86%) compared to Select Synch (66%) and MGA/Select Synch (68%); however, conception rate did not differ, 72, 63, and 62% for MGA/PGF, Select Synch, and MGA/Select Synch, respectively. Overall estrous response was higher for MGA/Select Synch (92%) compared to Select Synch (85%) but did not differ from the MGA/PGF (89%). The Select Synch (53%) and MGA/Select Synch (57%) protocols provided similar AI pregnancy rates compared to the MGA/PGF protocol (62%); however, there were considerably more heifers in estrus before the PGF injection in the protocols using GnRH.

Overall, the above protocols provide alternative methods for synchronizing estrus in beef heifers, and allow producers to estimate the costs associated with not using the MGA/PGF protocol. These data suggest that the MGA/PGF protocol with 19 days from the last feeding of MGA to PGF may be the best protocol provided producers can obtain consistent consumption of MGA.

Future Direction: Estrous synchronization is not listed among future ARS research objectives. Thus, future research will not continue in this area.

Relevant Publications:

Funston, R.N., R.P. Ansotegui, R.J. Lipsey, and T.W. Geary. 2002. Synchronization of estrus in beef heifers using either melengesterol acetate (MGA)/prostaglandin or MGA/Select Synch. Theriogenology 57:1485-1491.

Funston, R.N., R.P. Ansotegui, R.J. Lipsey, and T.W. Geary. 2002. Evaluation of melengestrol acetate/prostaglandin (MGA/PGF), Select Synch, and 7 d MGA/Select Synch estrous synchronization protocols in beef heifers. Proc. West. Sec. Am. Soc. Anim. Sci. 53:405-406.

Initiation and Synchronization of Estrous Cycles in Commercial Beef Herds for Natural Service

T.W. Geary

Problem: Most producers believe estrous synchronization is a tool used only for synchronization of estrus to facilitate use of artificial insemination (**AI**). However, synchronization of estrus is actually very applicable to natural service because it can often induce estrous cycles in anestrous cows or heifers and shorten the interval from calving to conception. It also gives cattle more opportunities to conceive during a defined breeding season, resulting in increased pregnancy rates, and earlier calving dates the following year, ultimately translating into older and heavier calves at weaning. Producers will likely only adopt an estrous synchronization protocol for natural service if it is cheap, easy to administer (generally requiring only one handling of cows), and effective on the majority of the cowherd. These studies make use of the facts that a single injection of prostaglandin (**PGF**) is only effective in cyclic cattle with a corpus luteum on their ovaries (approximately day 6 to 18 of the estrous cycle), that PGF is capable of terminating pregnancies, and that exposure of cows to bulls following calving shortens the interval to return to estrous cyclicity. The goal of these studies was to determine whether fertile bull exposure coupled with an injection of PGF could be used to synchronize the estrous cycles of cyclic and anestral cows and heifers.

Procedures: *Study 1.* The goal of this study was to determine whether an injection of PGF early in gestation would synchronize a fertile estrus in beef cows. One hundred-thirty non-lactating beef cows were divided to receive PGF at 25, 30, or 35 days of gestation or during the luteal phase of their estrous cycle (non-pregnant controls). Pregnant cows had been pre-synchronized with a single injection of PGF and bred natural service by one of six bulls. Cows that were bred following the pre-synchronized PGF injection and did not return to estrus before day 25, 30, or 35 were scanned for pregnancy using ultrasound to confirm pregnancy status. Cows receiving PGF at day 25 (n = 19), 30 (n = 20), or 35 (n = 21) received PGF on different dates (January 7, 12, and 17, respectively). On each date that pregnant cows received PGF, 23 or 24 control cows also received PGF. Cows were exposed to fertile bulls wearing chin ball marking harnesses from the time of PGF until February 21 resulting in a 46, 41, and 36-day breeding season for cows receiving PGF on January 7, 12, and 17, respectively. Estrual activity was observed twice daily in the morning and evening.

Study 2. The goal of this study was to evaluate fertile bull exposure with PGF compared to the MGA/PGF protocol for inducing and synchronizing a fertile estrus among beef heifers. One hundred sixty-five heifers were allotted by breed to receive either the melengestrol acetate/prostaglandin (**MGA/PGF**) protocol or fertile bull exposure (**BE**) with PGF to synchronize estrous cycles for natural service. Heifers receiving the MGA/PGF protocol were fed MGA (0.5 mg/head/day) for 14 days and received an injection of PGF 19 days after the last day of feeding MGA (Figure 1). Heifers receiving the BE/PGF protocol were exposed to fertile bulls beginning 33 days before the PGF injection. Bulls were removed from the BE/PGF treated heifers from day –6 to 0 (Figure 1). All heifers received the PGF injection on the same day (day 0) and were exposed to fertile bulls for 35 days at a bull:heifer ratio of 1:17 to 1:21.

Table 1. Pregnancy results of non-pregnant control cows receiving PGF during the luteal phase of their estrous cycle and pregnant cows at approximately day 25, 30, or 35 of gestation to terminate pregnancies and synchronize estrus for natural service

	Non-pregnant cows	Pregnant cows
PGF on day 25 (pregnant cows only)		
No. cows	24	19
Synchronized pregnancy rate	71%	68%
Breeding Season (44 days) pregnancy rate	83%	95%
PGF on day 30 (pregnant cows only)		
No. cows	23	20
Synchronized pregnancy rate	70%	79%
Breeding season (39 days) pregnancy rate	78%	95%
PGF on day 35 (pregnant cows only)		
No. cows	23	21
Synchronized pregnancy rate	65%	86%
Breeding season (34 days) pregnancy rate	91%	100%
Total		
No. cows	70	60
Synchronized pregnancy rate	69%	78%
Breeding season (34-44 days) pregnancy rate	84%	97%

Preliminary Findings: *Study 1.* Synchronized pregnancy rates of control cows and cows receiving PGF at approximately day 25, 30, or 35 of gestation were 69, 68, 79, and 86%, respectively (Table 1). Synchronized pregnancy rate of control cows and cows receiving PGF during early gestation (regardless of day) were also not different. Breeding season pregnancy rate of control cows and cows receiving PGF during early gestation (regardless of day) were not different.

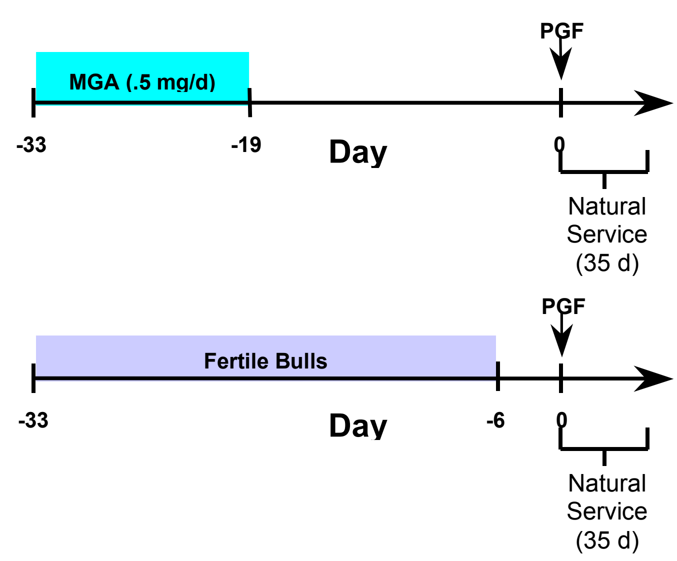


Figure 1. MGA/PGF and bull exposure with PGF protocols to synchronize estrus for natural service in beef heifers.

Exposure of prepubertal heifers and postpartum anestrous cows to bulls has been reported to decrease the age at puberty and decrease the postpartum interval. Whether fertile bull exposure coupled with an injection of PGF will terminate undesirable pregnancies and synchronize a fertile estrus for natural service is not known, as results from study 2 are not yet available.

Future Directions: We anticipate repeating Study 1 during the fall of 2002 to better determine whether fertility is improved among cows that lose pregnancies early during gestation. While repeating this study we will collect blood samples that may allow us to identify key hormones involved in fertility. Identifying fertility enhancing compounds may allow us to manage for improve fertility.

Relevant Publications: None at this time.

Effects of Feeding High Linoleate Safflower Seeds on Weaning and Reproductive Performance of Beef Heifers

T.W. Geary, E.E. Grings, and M.D. MacNeil

Problem: First-calf heifers experience longer postpartum intervals following calving and have lower pregnancy rates to defined breeding seasons than older cows. Both prepartum and postpartum nutrition have major effects on subsequent reproduction. Recent studies have suggested that dietary fat may play an important role in reproduction and cow productivity. Prepartum diets high in linoleic acid improved subsequent pregnancy rates and weaning weights in one study, but had no effect on these traits in another study. The objective of this study was to identify potential mechanisms by which prepartum diets high in linoleic acid might increase calf weaning weight and heifer re-breeding performance.

Procedures: Thirty-six Angus and Hereford-Angus heifers that conceived on the same day to one sire were randomized by weight and body condition score (**BCS**) to receive a prepartum diet high in linoleic acid (safflower) or control diet. Diets were equal in energy and protein and were fed as a total mixed ration. Heifers were fed in pens of six (three replicates per treatment) from day -56 until calving (day 0). At calving, heifers were housed together and fed the control diet until approximately day 120 postpartum. From day 120 postpartum until weaning, heifers were together on pasture. Hip height, body weight (**BW**), BCS, and ultrasound fat depth over the back and rump were measured every 28 days until the end of breeding. Dystocia score and calf vigor score were recorded at the time of calving. Within 12 hours postpartum, calf sex, calf birth weight, dam weight, and BCS were recorded. Calf weights were recorded at approximately 90 and 209 days postpartum and were adjusted for sex and age.

Blood samples were collected on days -56, -42, -28, -14, daily from day -10 to day 3, and twice weekly from day 0 to day 172 postpartum. Blood samples were analyzed for serum concentration of progesterone and leptin using radioimmunoassay. Elevated progesterone concentration was used to indicate return to estrous cycles after calving, and leptin concentrations were considered indicative of body fat stores.

Heifers were exposed to one bull from day 126 to 175 and examined for pregnancy by ultrasound on day 172 and 209. Ultrasound and twice weekly progesterone measurements were used to estimate date of conception. Data from three heifers experiencing health problems unrelated to the study were not included in the analyses.

Findings: There were no differences in body weight or BCS at calving between heifers fed safflower or control diets (Table 1). Body condition scores of heifers in both treatment groups increased during the first 28 days of the study and remained relatively high throughout the study (Figure 1). Calf birth weight and dystocia score did not differ between heifers fed safflower or control diets, but calf vigor was greater in calves born to heifers receiving safflower diets (Table 1). Gestation length was longer for heifers receiving safflower diets than for heifers receiving control diets (Table 1). The longer gestation length among heifers receiving safflower diets in the present study may account for the improved calf vigor at birth.

Table 1. Comparison of measurements recorded between heifers fed safflower or control diets for approximately 56 days before calving

	Control	Safflower
No. heifers per treatment	17	16
Heifer weight at calving, lbs	979	1003
Heifer body condition score at calving	5.4	5.3
Pregnancy rate, %	88	81
Postpartum anestrous interval, days	125	126
Calving to conception interval, days	140	135
Gestation length, days	281[a]	284[b]
Dystocia score	1.4	1.1
Calf vigor score	1.3[a]	1.0[b]
Calf birth weight, lbs	75	75
205-day weaning weight, lbs	510	530

[a, b] Cells within a row having different superscripts are different ($P < 0.05$).

Weight, BCS, fat depth over the back and rump, and hip height:weight ratio were not affected by prepartum diet or diet by day interaction. Serum concentrations of leptin did not differ between heifers fed safflower or control diets. Pregnancy rate, postpartum anestrous interval, and interval from calving to conception did not differ between heifers fed safflower or control diets (Table 1). Heifers fed safflower diets in the present study did not experience improved rebreeding performance as was reported by researchers who fed prepartum diets high in linoleate or other researchers who fed prepartum diets high in calcium soaps of fatty acids. The long postpartum anestrous intervals observed among heifers in the present study provided the opportunity for any potential benefit of fat supplementation during late gestation to have been detected, had it existed.

Calf weaning weights adjusted for age and sex were similar between treatments (Table 1). Others have reported increased calf gain from cows fed prepartum diets high in fat. While weaning weights did not differ, the difference in weaning weights of calves from heifers fed safflower and

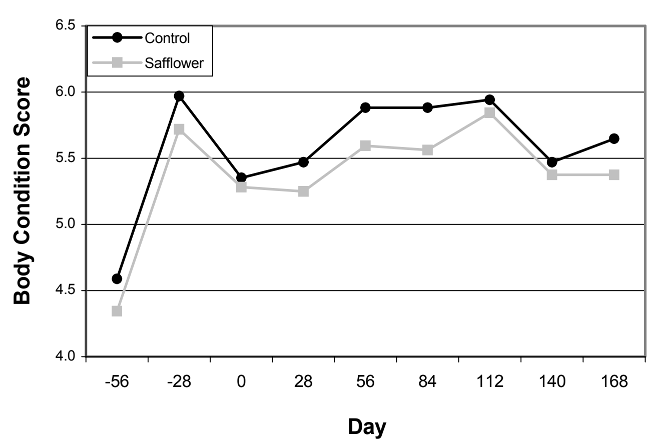


Figure 1. Average body condition scores of heifers fed control or safflower diets for 56 days prepartum (d 0 = calving).

control diets were of the same magnitude as those reported by Bellows et al. (2001). There may have been insufficient animals in the present study to detect such differences given the variation that typically exists among animals. The diets fed in the current study were similar in nutrient composition to diets fed previously. Safflower seeds (*Carthamus tinctorius L.*, variety Morlin) fed in this study were a genotype selected for high linoleate content.

This study was designed to identify the mechanism(s) by which supplemental fat in the prepartum diet might improve calf and rebreeding performance. Other than improved calf vigor, no differences were detected that would suggest any beneficial effect of providing first calf heifers a prepartum diet high in fat. However, given the typical variability among animals for many of the phenotypes observed, concluding that these diets had similar effects may be premature.

Future Direction: We do not anticipate any continued research in this area.

Relevant Publications:

Bellows, R.A., E.E. Grings, D.D. Simms, T.W. Geary, and J.W. Bergman. 2001. Effects of feeding supplemental fat during gestation to first-calf beef heifers. Prof. Anim. Sci. 17:81-89.

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. Anim. Sci. 77:824-834.

Effects of Feeding Whole Sunflower Seeds Before Artificial Insemination in Beef Heifers

R.N. Funston and T.W. Geary

Problem: Proper nutritional inputs are important for adequate growth and development of replacement heifers to ensure attainment of puberty and early conception in the breeding season. Yearling heifers that conceive early in the breeding season have greater lifetime productivity than heifers that conceive later in the breeding season. Replacement heifer development can be a major cost to a beef cattle operation. Producers need to minimize inputs yet achieve acceptable pregnancy rates. Heifer development systems are generally forage based; however, nonstructural carbohydrates, such as cereal grains, are generally required at some point in the feeding period to achieve weight gains needed for attainment of puberty before the breeding season. Supplemental lipids have been used to increase energy density of a ration and avoid potential negative effects on forage digestion associated with starch supplementation. Supplemental lipids may also have direct positive effects on reproduction in beef cattle independent of its energy contribution. The objectives of this study were to evaluate the effects of supplemental dietary fat on estrous response and fertility in beef heifers.

Procedures: Beef heifers from four locations (n = 1,014) were assigned by weight to treatment, within location, and randomly to artifical insemination (**AI**) sire. Whole sunflower seeds (2 lbs/head/day) were included in a total mixed diet for 60, 30, or 0 days before prostaglandin (**PGF**) injection. Heifers at Location 1 (n = 176) received sunflower seed diets for 0 or 60 days. Heifers at Location 2 (n = 397) were fed sunflower seeds for 0, 30, or 60 days. Heifers at Locations 3 (n = 211) and 4 (n = 230) received sunflower seeds for 0 or 30 days. Within location, diets were formulated to be similar in energy and protein.

All heifers received melengesterol acetate (0.5 mg/head/day) for 14 days followed 19 days later by an injection (25 mg) of PGF (day 0). Heifers were bred by AI approximately 12 hours after the onset of estrus until day 3 when all heifers which had not exhibited estrus were time inseminated. Pregnancy status was determined by ultrasound approximately 40 days after AI. Heifers were weighed approximately 60 days before and at the time of PGF, except at location 3 where weights were taken 30 days before PGF to determine if diet affected ADG.

Data were combined for Locations 1 and 2 to test the effect of 0 and 60 days sunflower feeding. Data from Locations 2, 3, and 4 were combined to test the effect of 0 and 30 day sunflower feeding.

Findings: Heifers fed the control diet had a greater (1.69 lbs/day) average daily gain (**ADG**) than heifers fed sunflower seeds (1.41 lbs/day) for 60 days. There was a location by treatment interaction for ADG in the comparison of 30 and 0 day sunflower treatments. Feeding greater than 5% of total dry matter intake as fat can markedly reduce fiber digestibility and reduce dry matter intake in ruminants. However, certain types of fat-containing feedstuffs have been fed at levels greater than 5% without negative effects. It is hypothesized that oilseeds can be fed at greater levels because ruminal metabolism of the oil is slowed by the fibrous seed coat and a portion actually bypasses through the rumen intact. It is possible that the sunflower feeding inhibited fiber digestion in the 60 day treatments and at Location 3 in the 30 day treatment.

There was no interaction of location and treatment in preliminary analyses; therefore, data were pooled across locations to test differences in fertility among all three treatments. Feeding sunflower seeds for either 30 or 60 days before AI did not affect the 72-hour estrous response or pregnancy rate. The 72-hour estrous response was 71% in the present study. Pregnancy rate by location and treatment are presented in Table 1. Pregnancy rate for heifers detected in estrus was 68% compared to 33% for heifers inseminated at 72-hours after PGF. Regardless, no differences in final pregnancy rate were detected. Heifers in the present study were all in adequate body condition (**BCS** 5 to 6). Cattle experiencing a greater nutritional challenge appear to be more responsive to supplemental nutrients. There may have been a positive response to fat supplementation had the heifers been nutritionally stressed. In summary, feeding 2 lbs of whole sunflower seeds for either 60 or 30 days before AI did not improve estrous response or pregnancy rate in beef heifers in good body condition.

Table 1. Pregnancy rate (%) by location for heifers fed 2 lbs/day of sunflower seeds for 0 (control), 30, or 60 days

		Treatment		
Location	No. heifers	Control	30 day sunflower	60 day sunflower
1	176	55		45
2	397	61	66	61
3	211	56	62	
4	230	54	52	

Future Direction: No additional studies are planned at this time.

Relevant Publications:

Lammoglia, M.A., R.A. Bellows, E.E. Grings, J.W. Bergman, R.E. Short, D.M. Hallford, and R.D. Randel. 2000. Effects of dietary fat and sire breed on puberty, weight, and reproductive traits of F1 beef heifers. J. Anim. Sci. 78:2244-2252.

Prepartum Supplementation with Protein or Fat and Protein for Grazing Cows in Three Seasons of Calving

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

Problem: Several reports have suggested that supplementation of beef cows with dietary fat either before or after calving can improve their reproductive performance. While some studies have shown positive responses to fat feeding, others have not. We believe some of the difference between experiments is due to the nutritional quality of diets fed between calving and breeding. Cows grazing rangelands exist under a dynamic environment where rapid changes in forage quality can occur. Time of calving and individual years can have significant impacts on the quality of diets for grazing cows both before and after calving. This varied forage quality may have some effect on the response to fat supplementation. Much of the research testing the effects of fat supplementation on reproduction has been conducted with first-calf heifers. These heifers are under greater nutritional stress than older cows because of the compounding need for nutrients for both growth and milk production. Therefore, young cows may be more sensitive to dietary fat levels than older cows.

Procedures: To take a closer look at the interaction of pre- and post-calving forage quality on response to fat supplementation and to look at the effect of cow age, we conducted a study during two winter/spring periods using both 3-year-old and 5 to 7-year-old beef cows. Additionally, these cows were due to calve at one of three times, February, April, or June. This allowed us to observe the effects of varied forage quality on response to supplementation. Cows grazing native range were supplemented with either protein and fat using safflower seed and safflower meal or were supplemented with protein but not fat using safflower meal and barley. Cows were moved to a drylot for calving and were fed hay and supplement until they calved. The total days of supplementation during the grazing and drylot periods averaged 71 days.

Findings: Quality of grazed forage was very different for cows calving at the three different times. Average crude protein varied from about 5% for cows calving in February to 11% for cows calving in June (Table 1). One question about fat feeding with poor quality range forage, like that for the February calving cows, is whether fat has a negative effect on the digestion of forage. We tested this in the laboratory and found that fat supplementation was not affecting forage digestibility even for the lower quality diets. However, levels of fat higher than those studied could affect forage digestion.

Table 1. Quality of range forage portion of diets for cows calving in three seasons

	Season of calving		
	February	April	June
Year 1			
Crude protein, %	5.5	7.6	13.8
Ether extract, %	2.3	1.4	1.8
Year 2			
Crude protein, %	4.9	4.5	7.4
Ether extract, %	1.4	1.4	1.7

Cows calving in June gained about 80 pounds more during the precalving period than other calving groups and were in better body condition at calving. February calving cows lost condition during the grazing season, whereas June calving cows gained condition during this period. Body condition scores (**BCS**) at calving were low for 3-year-old cows, averaging only about 4, compared to 5 for older cows (Table 2). This indicates that there was nutritional stress placed on the young cows. Cows fed only protein in the February calving group had higher body condition scores compared to those receiving protein plus fat; the opposite was true for the April calving cows, and there was no difference due to supplement type in the June calving group. Any effects of the type of precalving supplement on weight or body condition were gone by the beginning of the breeding season.

Table 2. Body condition score at calving for 3-year-old or 5-year-old plus cows fed either protein only or protein plus fat

	Season of calving					
	February		April		June	
Cow age	3	5+	3	5+	3	5+
Protein only	4.3	5.2	3.6	4.6	4.8	5.5
Protein plus fat	4.0	5.1	4.2	5.2	4.6	5.4

Three-year-old cows calving in February and 5-year-old cows calving in April fed supplements with both protein and fat had greater pregnancy rates than cows fed protein only, but the opposite was found for 3-year-olds calving in April (Table 3). In this last group, 97% of the cows fed protein became pregnant compared with only 63% of the cows fed protein plus fat. Pregnancy rates of cows calving in June was not affected by the type of supplement they received before calving. It should be noted that cow numbers within each year were small and there were differences between years.

Table 3. Percentage of cows pregnant for 3-year-old or 5-year-old plus cows fed either protein only or protein plus fat

	Season of calving					
	February		April		June	
Cow age	3	5+	3	5+	3	5+
Protein only	75	93	97	80	86	93
Protein plus fat	93	84	63	99	80	93

This study showed that varying conditions associated with season of calving affect cow performance and response to supplementation. For most cows in this study, reproduction was not impaired and there may have been no need of additional fat to >turn-on= reproductive signals. However, reproduction was low in 3-year-old cows calving in April and providing a high fat supplement before calving did not improve this situation. These cows were under some degree of nutritional stress as evidenced by low condition scores at calving (they averaged less than 4). These cows may have been using the fat as an energy source for themselves rather than to trigger reproduction. This theory may be supported by the fact that BCS in 3-year-old April-calving cows receiving protein plus fat were about half a condition score higher than those receiving only protein.

These results differ from previous studies where pregnancy rate was improved by including safflower seed in the diets of first-calf heifers. Differences in how cows respond to dietary fat may be related to cow age or diet nutrient concentrations both pre- and post-calving. Higher body condition cows (i.e., June-calving cows receiving high post-calving nutrition associated with early summer forage) may be in adequate nutritional status and may not benefit from fat supplementation. Young cows under nutritional stress, (i.e., 3-year-old April-calving cows) may use the fat as to improve their own condition rather than as a reproductive trigger. The best response to fat supplementation may occur in young, moderate condition cows receiving moderate post-calving nutrition.

Future Direction: No further studies are currently planned to evaluate fat supplementation. Researchers at other locations are attempting to evaluate the mode of action of fat supplementation on reproduction.

Relevant Publications:

Grings, E.E., R.E. Short, M. Blummel, M.D. MacNeil, and R.A. Bellows. 2001. Prepartum supplementation with protein or fat and protein for grazing cows in three seasons of calving. Proc. West. Sec. Amer. Soc. Anim. Sci. 52:501-504.

Effects of Varying Energy Intake and Sire Breed on Duration of Postpartum Anestrus, Insulin-Like Growth Factor, and Growth Hormone in Mature Crossbred Cows

A.J. Roberts and T.G. Jenkins

Problem: Adverse effects of under-nutrition on reproduction have been known for years. Because of this, it is important for producers to match animal requirements to specific environmental conditions and management practices in order to optimize production efficiency. Understanding how an animal perceives itself to be nutritionally stressed can assist in matching animals with production environments. Previous research indicates that circulating concentrations of insulin-like growth factor (**IGF-1**) and growth hormone (**GH**) fluctuate in response to nutrient status, and may be indicative of a cow's ability to resume cycling in the postpartum period. However, little is known about the genetic variation associated with these hormones. As different breeds or breed types may respond differently to variations in levels of feed intake, it was the objective of this study to evaluate effects of sire breed and level of daily metabolizable energy intake on postpartum anestrus and nutritional status, as assessed by levels of IGF-1 and GH, in F_1 cows out of Angus or Hereford dams.

Procedures: Five to eight-year-old F_1 cows out of Angus or Hereford dams and either Angus, Hereford, Shorthorn, Galloway, Longhorn, Nellore, or Salers sires were fed one of three levels of daily metabolizable energy intake (**DMEI**; 132 or 189 kcal ME/kg metabolic body weight or allowed ad libitum access; 6 to 8 cows/BREED/DMEI). Circulating concentrations of progesterone in weekly blood samples collected 2 to 14 weeks after calving were used to predict length of postpartum anestrus. Concentrations of IGF-1 and GH were determined at week 2, 4, 8, and 14 to evaluate changes in nutritional status (i.e., high GH and low IGF-1 indicates negative energy balance). Within cow linear regressions were used to estimate intercepts and slopes for IGF-1 and GH. The slopes were then used to indicate if hormone levels were going up or down over time. Analyses of variance were used to evaluate fixed effects of BREED, DMEI, and interaction of BREED and DMEI on length of anestrus, slopes and intercepts of IGF-1 and GH, and concentration of each hormone at week 2 postpartum.

Findings: Proportion of cows that resumed cycling during the 14 week period after calving was less in animals fed the low level of DMEI (37/49) than in cows given ad libitum access to feed (47/49); proportion of cows fed at 189 kcal ME that resumed cycling (45/47) was not different from cows given free choice access to feed. For Galloway, Longhorn, and Nellore sired cows, but not cows sired by other breeds, length of postpartum anestrus was longer in cows fed the low level of DMEI than cows fed at higher levels. Restricted feeding resulted in decreased concentrations of IGF-1 2 weeks after calving in cows sired by some, but not all breeds. As lower values would be indicative of decreased energy status, these findings indicate that sire breed influenced how cows responded to dietary restriction. In general, slope of IGF-1 changed from a negative value towards a positive value as DMEI increased but magnitude of change between levels of DMEI varied by sire breed. A negative slope indicates that animals are in a negative energy balance (i.e., IGF-1 decreased over time) whereas slopes approaching zero or positive numbers would be indicative of little change or increased energy balance respectively. Concentrations of GH increased at a greater rate over time in cows from the 132 kcal DMEI group compared to cows from either of the other DMEI groups. However, sire breed did not affect GH. Increases of GH over time are also indicative of animals in a negative energy balance. These results indicate that sire breed may influence a cow's response to dietary restriction, and that circulating concentrations of IGF-1 may provide an objective tool for evaluating a cow's nutritional status.

Future Direction: Additional studies are being conducted to establish if measurements of IGF-1 concentrations in blood can be used as an indicator of efficiency, if so this will provide a method to assist in selecting cows best suited for particular nutrient environments.

Relevant Publications:

Roberts A.J. and T.G. Jenkins. 2002. Effects of varying energy intake and sire breed on duration of postpartum anestrus, IGF-1 and GH in mature crossbred cows. Proc. West. Sect. Amer. Soc. Anim. Sci. 53:454-456.

Roberts, A.J., R.A. Nugent III, J. Klindt, and T.G. Jenkins. 1997. Circulating insulin-like growth factor I, insulin-like growth factor binding proteins, growth hormone, and resumption of estrus in postpartum cows subjected to dietary energy restriction. J. Anim. Sci. 75:1909-1917.

Evaluating New Measurements of Fertility in Beef Cows

T.W. Geary and G.A. Perry

Problem: Loss of pregnancy early in gestation appears to be a major source of reproductive inefficiency among beef and dairy cattle. Prevention of these losses requires characterization of the losses with regards to when and why they occur during gestation. Use of ultrasound allows pregnancy diagnosis as early as 25 days after breeding. Additionally, because fertilization rate is approximately 90% and pregnancy rates at day 25 are generally less than 75%, losses must occur before day 25 of gestation. However, about a 20% incidence of early embryonic mortality has been reported in dairy cows from day 28 to day 98 after insemination following the Ovsynch estrus synchronization protocol. Other laboratories have recently identified biological compounds in the bloodstream of the pregnant cow that can be detected as early as day 18 following breeding that may allow characterization of earlier pregnancy losses earlier than can be determined by ultrasonography.

Preliminary studies, conducted at the University of Missouri, suggest that size of the ovarian follicle that releases the egg that becomes fertilized following mating is related to successful establishment and maintenance of pregnancy. More specifically, ovulation of larger follicles appears to result in higher initial pregnancy rates and less embryonic mortality. It is tempting to speculate whether these losses occurring before 25 days of gestation are also associated with size of the ovulatory follicle since cows that ovulated smaller follicles also had lower initial pregnancy rates. The mechanisms by which this might occur are unclear, but may involve maturity level of the developing egg within follicles of different sizes or the ability of those follicular cells to produce progesterone (a hormone involved with maintenance of pregnancy) after ovulation has occurred. Losses, occurring early in gestation, collectively may account for a very substantial portion of the reproductive inefficiency observed in beef cattle. The goal of this study was to confirm earlier findings and try to better understand when and why embryonic mortality occurs.

Procedures: Composite cows (n = 273) were bred during a 30-day synchronized artificial insemination (**AI**) breeding season to sires of similar genetic makeup. Cows were fitted with electronic transmitters (**HeatWatch**) to facilitate estrous detection. Females expressing estrus, as determined visually or electronically, were inseminated 8 to 16 hours after their initial expression of estrus. Follicular development around the time of estrus or induced ovulation was characterized using ultrasonography. Blood samples and ultrasound data will be used to verify ovulation and to assess pregnancy status at several time points following breeding (Figure 1).

To facilitate collection of data, cows were prepared for breeding using the CO-Synch protocol [an injection of gonadotropin-releasing hormone (**GnRH**) on day –9, an injection of PGF on day –2, and another injection of GnRH on day 0 at which time all females not previously detected in estrus were artificially inseminated]. Ovaries were visualized with ultrasound and location of follicles greater than 8 mm were recorded at time of PGF injection and again on day 0 to identify and record size of the dominant follicle 24 hours before anticipated ovulation. Ovaries of all cows detected in estrus between day –3 and day 30 were examined with ultrasound within 12 hours of their initial expression of estrus to record size of the dominant follicle. Cows expressing estrus were artificially inseminated immediately following ovarian examination. Ovulation of the dominant follicle was confirmed in all cows 2 days following AI using ultrasonography. Pregnancy will be diagnosed on day 13 and 18 following AI by differential expression of a pregnancy specific protein (MX; in collaboration with Dr. Troy Ott, University of Idaho), and on day 27, 40, 54, and 68, using ultrasound. Progesterone concentration will be measured in each blood sample collected on day 13, 18, 27, 40, 54, and 68 to analyze for differences due to follicle size or nutritional treatment and to help characterize pregnancy failures.

It is possible that differences in ovulatory follicle size between cows may be the result of induced ovulations with GnRH rather than what might occur during natural or induced estrus. Follicular measurements collected at the time of AI among cows that return to estrus during the breeding season will be used to determine whether variation in ovulatory follicle size occurs during natural estrus.

Preliminary Findings: The preliminary data collected by frequent visualization of ovarian follicle size changes and frequent determination of pregnancy in 36 cows as illustrated in Figure 2. Confirmation of these results with the present study may improve our ability to obtain higher pregnancy rates and help identify causes of early pregnancy failures that have not been previously reported in beef cattle. It is also interesting to note that although initial pregnancy rates were lower among anestrous cows, there was no embryonic loss after day 25 of gestation (Table 1). Progesterone concentrations following ovulation of different sized follicles also differed from day 10 to 22 following insemination and may be related to the establishment and maintenance of pregnancy (Figure 3). We believe that further characterization of early pregnancy losses will lead to better management and improved synchronization protocols that may improve pregnancy rates to AI and natural service.

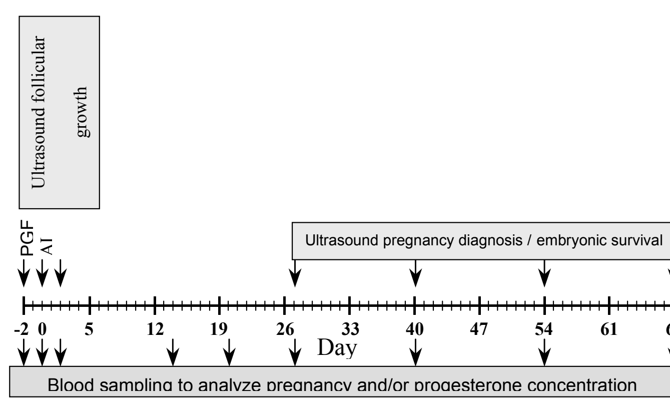


Figure 1. Data collection schedule to characterize effects of follicular size at time of ovulation on establishment and maintenance of pregnancy (day 0 = anticipated estrus or AI +GnRH).

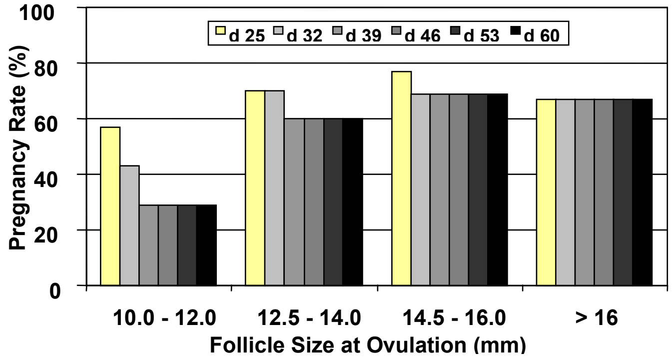


Figure 2. Preliminary data of the effects of follicle size at the time of induced ovulation on establishment and maintenance of pregnancy measured at 25, 32, 39, 46, 53, and 60 days of gestation as determined using ultrasound.

Table 1. Pregnancy rates on days 25 and 60 post-insemination by treatment and follicle size class

	Cyclic cows		Anestrous cows	
Follicle size class	Day 25	Day 60	Day 25	Day 60
10-12 mm	60%	20% [c]	50%	50%
12.5-14 mm	100%	86% [d]	33%	33%
14.5-16 mm	100%	100% [d]	63%	63%
>16 mm	67%	67% [cd]	67%	67%
Total	85% [a]	68%	56% [b]	56%

[a, b] Cells within a row having different superscripts are different (*P* = 0.06).
[c, d] Cells within a column with different superscripts are different (*P* < 0.05).

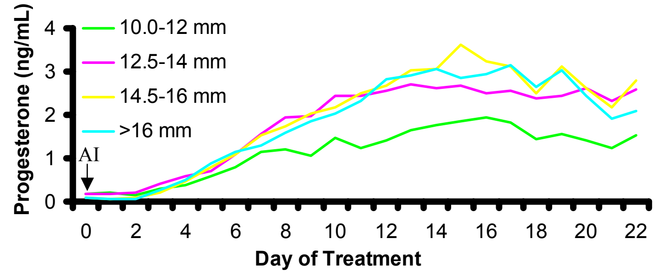


Figure 3. Subsequent progesterone concentration of cows following ovulation of different sized follicles.

Future Direction: Initial results are similar to our preliminary findings. Final analyses of blood samples still needs to be conducted. Our future direction in this area will depend on our results of our final analyses this fall.

Relevant Publications:

Perry, G.A., T.W. Geary, M.C. Lucy, and M.F. Smith. 2002. Effect of follicle size at time of GnRH-induced ovulation on luteal function and fertility. Proc. West. Sec. Am. Soc. Anim. Sci. 53:45-48.

Heifer Development Within Three Seasons of Calving

E.E. Grings, R.E. Short, T.W. Geary, and M.D. MacNeil

Problem: Development of replacement heifers is a critical component of a beef production enterprise. Altering seasons of calving and weaning to manipulate the match-up of cow nutrient requirements with forage quality dynamics affects calf weight at weaning and subsequent management of heifer calves in anticipation of the entry into the breeding herd. Altering harvested feed inputs into the replacement heifer program will impact cost of raising a heifer from weaning to breeding. The objective of this study was to evaluate the potential for decreasing harvested feed inputs into development programs for heifers born in different season and exposed to differing nutrient patterns from birth until first breeding.

Procedures: Heifer calves born in February were weaned in August (6-months of age) or October (8-months of age) and heifers born in April or June were weaned in October (6- or 4-months of age) or December (8- or 6-months of age). Heifers were managed to enter breeding herds associated with their season of calving. About 3 weeks after weaning, calves were weighed (initial weight) and placed in drylots or on pasture. Heifers in drylot were fed a corn silage and hay-based diet. Heifers on forage treatments were placed on pasture but were fed grass hay and/or a supplement depending on forage conditions. Three months before their respective breeding seasons, heifers on forage were moved to drylot and fed a corn silage and barley-based diet (February or April) or to high quality spring pasture (June).

Findings: Rates of gain during drylot and forage phases differed with season of calving, weaning time, and post-weaning management. Overall, for heifers weaned at 6-months of age, gains were greatest in February followed by April and then June (1.61 versus 1.43 versus 1.36 lbs/d). Overall gains were 1.69, 1.43, 1.21 lbs/d for 8, 6, and 4 months weaned in October. Overall gains were less for heifers on forage than drylot treatments (1.45 versus 1.52 lbs/day). Weight at the beginning of the breeding season did not differ with postweaning treatment but were affected by season of calving and weaning age reflecting differences in initial weights. Prebreeding weights for heifers weaned at 6-mo were 858, 812, and 748 lbs for heifers born in February, April, or June and were 849, 812, and 715 lb for heifers weaned in October at 8, 6, or 4-months of age. Proportion of heifers cycling at the beginning of the breeding season was greater for heifers in drylot (0.98) than forage treatments (0.92). Season of calving and weaning age effects on initial weight carried through to weight at breeding but did not affect cyclicity of beef heifers. Post-weaning management affected proportion of heifers puberal by breeding even when weights at breeding were similar. While stair-step growth programs have successfully been used to raise heifers from weaning to breeding, it is important to provide adequate nutrition to these heifers during the slow growth phases so as not to limit overall rate of gain. Heifers from different calving times may have different forage sources available to them which results in different rates of gain and different growth patterns from weaning to breeding.

Future Direction: These systems for raising heifers have been repeated in one more year. These heifers have been maintained within their respective seasons of calving and any long-term effects of these development programs will be monitored.

Relevant Publications:

Grings, E.E., R.E. Short, T.W. Geary, and M.D. MacNeil. 2002. Heifer development within three seasons of calving. Proc. West. Sec. Amer. Soc. Anim. Sci. 53: 261-

Table 1. Rate of gain, weight, and cyclicity of heifers born in 3 seasons, weaned at two ages, and reared on different management strategies based primarily in the drylot (D) or on forage-based (F) diets

	February-born				April-born				June-born				
	6-month		8-month		6-month		8-month		4-month		6-month		
	D	F	D	F	D	F	D	F	D	F	D	F	SEM
No. of heifers	43	46	41	38	46	44	41	40	39	37	34	34	
ADG, lbs/d													
Slow	1.45	0.66	1.50	0.04	1.58	0.37	1.76	0.48	1.61	0.99	1.83	1.28	0.011
Fast	1.85	2.82	1.94	2.79	1.41	2.71	1.47	2.62	0.59	1.47	0.81	1.39	0.018
Overall	1.63	1.61	1.76	1.63	1.50	1.34	1.61	1.63	1.25	1.17	1.43	1.34	0.011
Weight, lbs													
Initial	508	510	570	574	493	495	519	521	378	378	418	442	0.11
At diet change	686	592	673	576	693	541	658	557	658	508	656	559	2.88
Prebreeding	860	858	856	843	827	794	796	803	728	702	746	750	3.61
% Cycling	100.0	97.7	97.9	90.6	100.0	91.3	97.6	90.5	94.4	92.5	96.4	86.4	0.043
No. days slow	122	122	69	69	126	126	80	80	183	183	139	139	
No. days fast	94	94	94	94	94	94	94	94	94	94	94	94	
No. days total	216	216	163	163	220	220	174	174	277	277	233	233	

A Model for Determining Risk of Pine Needle Abortion in Cattle Calving at Different Times of the Year

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

Problem: Consumption of needles from Ponderosa pine trees (*Pinus ponderosa*) cause cattle to abort. Loses due to pine needle abortions are a multimillion dollar problem for cattle producers in the Western United States. In order to decrease these loses, producers need to be able to manage risk which is determined by the risk of consumption and the risk of an abortion once pine needles are consumed. The risk of consumption is primarily related to cold weather and storms. The risk of an abortion after consumption of pine needles is determined by the amount of needles consumed and stage of pregnancy. We found that pine needle-induced abortions did not occur during the first half of pregnancy, but the effect increased markedly during the second half of pregnancy with most cows aborting when pine needles were consumed after 250 days of pregnancy. In order to objectively assess the potential role of calving date in pine needle abortion risk, a model was developed to combine the risk of consumption of pine needles and the risk of an effect once needles are consumed. That model was then used to assess the role of calving date in pine needle abortion risk.

Procedure: Risk of pine needle consumption was assumed to be primarily related to low temperature. There are undoubtedly other factors such as wind speed, snow, storms, snow depth, stress, age-of-cow, and nutrient intake and balance, but most of these factors are either directly or indirectly related to low temperature. A threshold temperature of -10EC (14EF) was chosen as the point at which cows would be sufficiently stressed to increase feed intake to result in pine needle consumption. A weather data set for Miles City, MT, that included daily minimum and maximum temperatures for the period January 1893 through August 2000 was obtained from the National Climatic Data Center, National Oceanic and Atmospheric Administration (www.ncdc.noaa.gov). For each day of the year, the number of observations where the minimum temperature was -10EC (14EF) was divided by the total number of observations to get the probability of a low temperature (**PT**). The PT for each day of the year were averaged for bimonthly periods (1st of month = 24th of preceding month through the 8th of the current month and 15th of the month = 9th through the 23rd of the current month). A regression of probability of an abortion (**PA**) resulting when pine needle consumption started on that day of pregnancy was also calculated. Cows were simulated to calve at 24 bimonthly dates (1st and 15th of each month) during the year. For each simulated calving date, the average PT and the PA values for each bimonthly interval were multiplied together, multiplied by 15 (to get a bimonthly equivalent risk), and summed for the year to obtain a cumulative relative risk of pine needle induced abortions for each calving date.

Findings: The probabilities for low temperatures based on historical records for this location are shown in Figure 1. As we might expect, the greatest risk for low temperatures is from January 1 to February 1 (actually December 23 through February 8) with the risk falling dramatically as dates progress away from those dates. The shape of this curve and its location along the date axis will probably be similar for other sites in North America. The main difference for other sites will be the relative position on the Y axis. For more moderate temperature locations, the curve will be lower, and for more extreme cold locations, the curve will be higher. Therefore, it will be important for producers to develop a temperature probability curve for their own location.

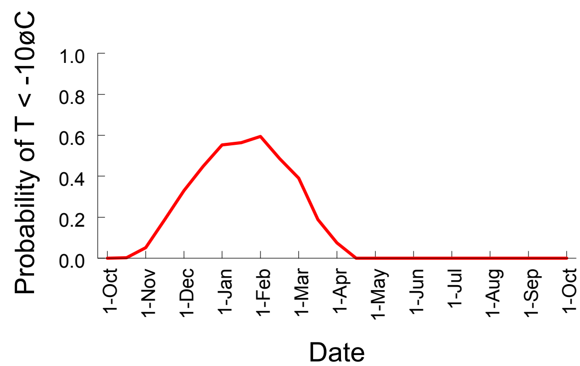


Figure 1. Probabilities of temperatures (T) being # -10EC (14EF) during the year at Miles City, MT.

The regression analysis of our previous data showed that the relationship of the probability of an abortion and day of gestation was a piecewise linear regression. The probability was 0 during the part of the year that cows were not pregnant and from day 1 through day 120 of gestation, and it was 1 from day 255 through calving. The linear regression from day 120 to day 255 of gestation was PA = -88 + .74d where d is the day of gestation at the start of pine needle feeding. As an example, this piecewise regression is shown in Figure 2 for cows calving on April 1 or July 1. The same regression was applied to all simulated calving dates. As opposed to the temperature curve which changes with different locations, this curve will remain constant for all locations. However, it will shift along the date axis as calving date changes.

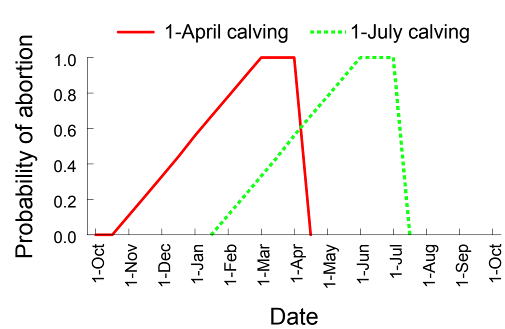


Figure 2. Effect of day of gestation (date) on probability of pine needles causing an abortion for cows calving April 1 or July 1.

The data for total cumulated risk of pine needle-induced abortions obtained by combining the probabilities for low temperatures and for abortions during pregnancy for cows that calve at different times of the year are shown in Figure 3. This figure shows the total cumulated relative risk that cows are exposed to during pregnancy. For the simulated data from Miles City, MT, the greatest risk is for cows calving March 1 with the relative risk being high for cows calving from January 15 to May 1. Very low risk is experienced when cows calve from June 1 through December 15. For locations that would have lower risks of cold temperatures as shown for the warmer location in Figure 3, the total cumulated risk is dramatically reduced and the period for very low risk is expanded to May 1 through January 1.

This simulation clearly demonstrates that season of calving can be used to manage the risk of pine needle induced abortions. Whether or not changing calving season is a viable alternative for individual producers will depend on how severe their risk is of pine needle abortion and how changing calving season will affect other economic and risk aspects of their operation.

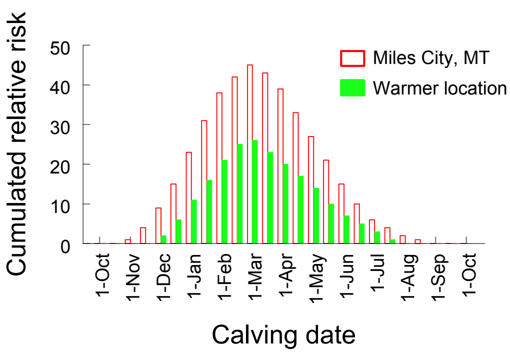


Figure 3. Cumulated relative risk of pine needle induced abortions for cows calving at different dates during the year at Miles City, MT, or a warmer location.

There is a perception among producers that pine-needle induced abortions are more of a problem today than they were in the past. Cows are not likely to be more susceptible to the effects of pine needles now than they were in the past because we have found that a wide array of breeds and breed crosses tested in many situations are all affected by pine needles. If this perception is true, it is more likely due to changes in management such as moving calving from summer to winter or spring, although increased awareness of the problem also could be a factor.

Cow-calf producers in areas with Ponderosa pine trees are at risk of production loses due to pine needle induced abortions. The level of risk is determined by a combination of the risk of cows eating pine needles and the risk of an effect once pine needles are eaten. Little can be done to alter the risk of an effect once needles are eaten, but producers can minimize risk of consumption by changing season of calving. Calving in summer or fall will have little risk of pine needle abortion. For producers in areas with similar cold temperature profiles as at Miles City, MT, risk of abortions is highest for cows calving from January 15 through May 1. Locations with a lower risk of cold temperature will have a lower risk of abortions and a shorter time period where calving season has a high risk.

Future Direction: No additional research is planned on pine needle abortion.

Relevant Publications:

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.

Dehority, B.A., E.E. Grings, and R.E. Short. 1999. Effects of cross-inoculation from elk and feeding pine needles on the protozoan fauna of pregnant cows: Occurrence of *Parentodinium africanum* in domestic U.S. cattle (*Bos taurus*). J. Eukaryotic Microbiology 46:632-636.

Ford, S.P., L.K. Christenson, J.P. Rosazza, and R.E. Short. 1992. Effects of Ponderosa pine needle ingestion on uterine vascular function in late-gestation beef cows. J. Anim. Sci. 70:1609-1614.

Ford, S.P., J.P. N. Rosazza, M.S. Al-Mahmoud, S. Lin, D.B. Farley, and R.E. Short. 1999. Abortifacient effects of a unique class of vasoactive lipids from *Pinus ponderosa* needles. J. Anim. Sci. 77:2187-2193.

Short, R.E., E.E. Grings, M.A. Lammoglia, C.A. Davison, N.J. Biensen, and S.P. Ford. 1997. Effects of elk and cattle rumen contents and dietary fat on abortifacient activity of pine needles. J. Anim. Sci. 75(Suppl. 1):117.

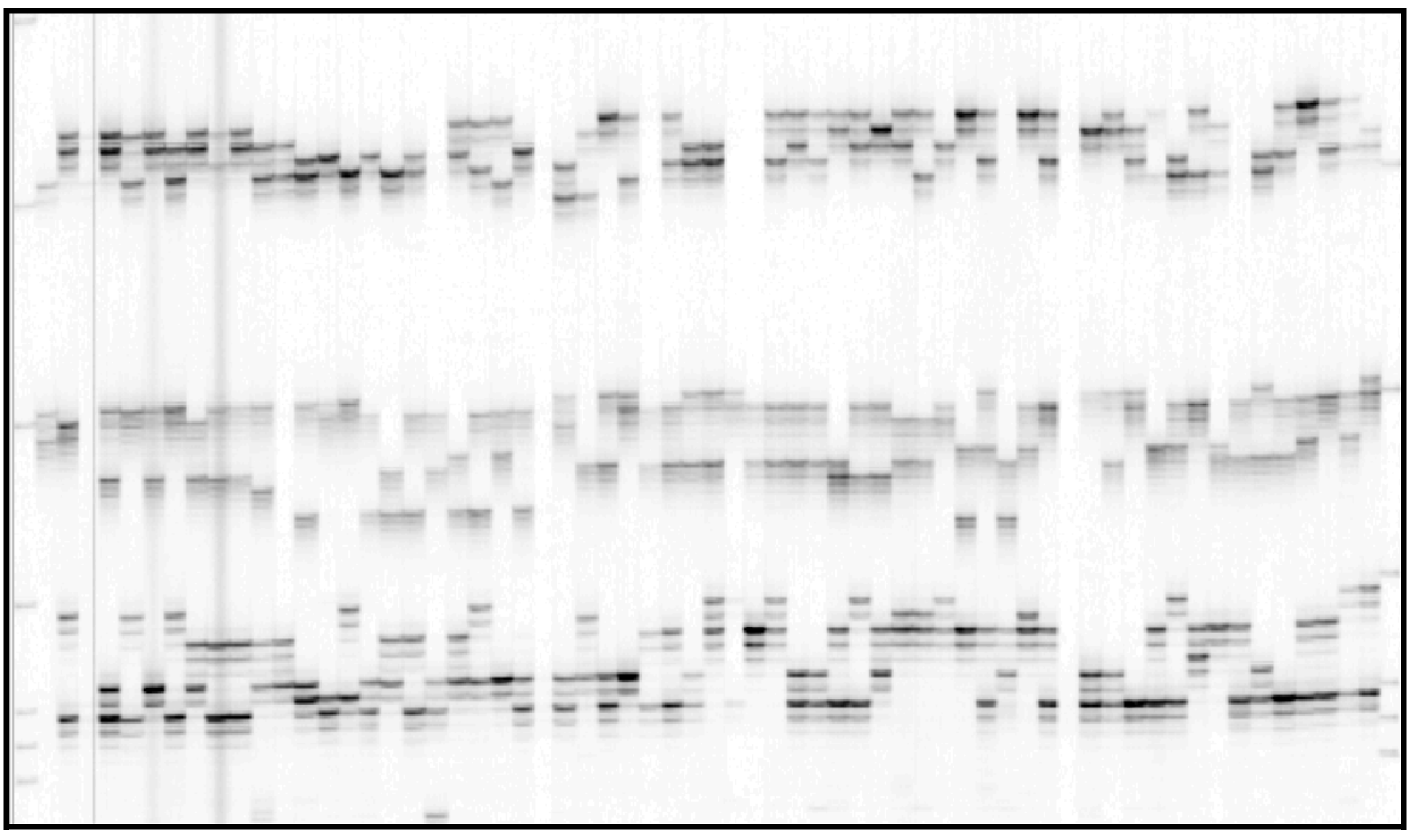
Thrift, T.A., R.E. Short, and R.D. Randel. 1997. Effects of feeding two species of pine needles to *Bos taurus* and *Bos indicus* cows. J. Anim. Sci. 75(Suppl. 1):4.

D. Genomic Solutions

Rapid advances in our understanding of the genome have made possible new approaches to longstanding problems in animal breeding. Improving traits that are measured late in life or can only be measured after death is slow using conventional breeding strategies. Genetic markers that are associated with these economically important traits can be identified and used to make selection decisions much earlier in an animal's life. These markers can also be used in migrating novel genes (i.e., for disease resistance) into a commercially relevant stock.

Genetic technologies can be used to objectively address questions of bio-diversity. Breed associations might consider using a panel of markers to monitor the grading up process. Broad sampling of breed resources is key to the national initiative to conserve them for posterity. Genetic distances between populations also provides insight as to their uniqueness that is less subjective than prior evaluations based on appearance.

Our work in identifying these genetic solutions depends in part on several partners. Collaboration with the USDA-ARS Meat Animal Research Center has been essential. Cooperation with colleagues at Colorado State University, Texas A&M University, and University of Missouri have enhanced our capacity. The financial support of LGL Alaska Research and the Montana Beef Council made some of this research possible and is greatly appreciated.



Principles and Applications Of Genomics

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**). Cattle cells contain 30 pairs of chromosomes.

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).

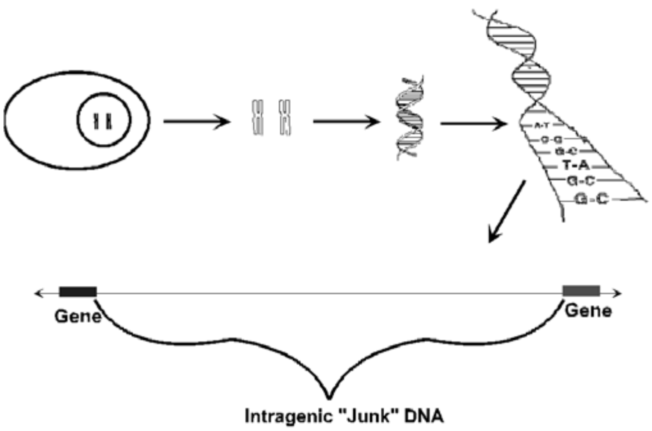


Figure 1. Structures of DNA. Intragenic DNA (DNA whose function is, as of yet, unknown) makes up about 99% of all DNA.

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 30,000 genes, in the bovine genome. 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.

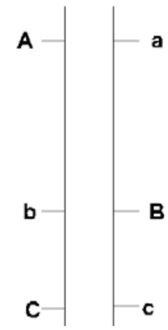


Figure 2. A hypothetical pair of chromosomes with 3 genes ("A," "B," and "C") and two alleles for each gene (uppercase and lowercase).

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 observing 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 determined 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, therefore, called a "**QTL**" (Quantitative 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: **phenotypic**, 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 "mapping" 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, eliminating 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

Genomic science offers new opportunities to address problems of livestock producers and natural resource managers. Identifying QTL provides initial leads toward understanding the basis for observed differences in performance between populations or breeds. Follow-up investigations can then result in selection strategies that accelerate genetic improvement of economically important traits. Traditional breeding systems coupled with the use of genomic markers may also introduce specific novel genes into commercially relevant breeding stocks. Finally, biodiversity of natural populations can be objectively resolved using genomic technologies.

Using Markers to Introduce Novel Genes into Breeding Stocks

M.D. Grosz and M.D. MacNeil

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 six 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 and well-being, an 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; ½ Red Angus,¼ Tarentaise, ¼ Charolais) cows. These cross-bred bulls were then mated [by artificial insemination (**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 ¾ Hereford, ¼ CGC or ¾ CGC, ¼ Hereford ancestry). Animals were scored as either non-white or white-faced based on visual observation.

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.

After preliminary identification of the genomic region that contained the causal gene for white-face, additional markers within the region were used to further narrow the location of interest. Additional mapping data were also obtained from USDA-ARS, Meat Animal Research Center, Clay Center, Nebraska.

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 two copies of the Hereford allele appear as Herefords. Animals with no copies of the Hereford allele appear as non-white faced animals. But animals with one copy (such as Hereford crosses, or baldies) have limited non-pigmented areas.

Marker analysis indicated the presence of genetic linkage between markers (CA028 and KIT 15-1) on bovine chromosome 6 and the white face phenotype (Figure 1). The degree of linkage observed is sufficient to identify flanking markers that can be used to assist the migration of the allele for the non-white-face phenotype from CGC into Hereford.

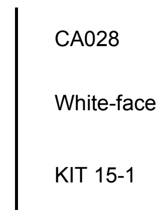


Figure 1. Map of the region of bovine chromosome 6 containing the gene for the white-face phenotype.

In addition, several genes have been identified as "candidate" genes for causing the white face phenotype characteristic to Hereford cattle.

Future Direction: An experiment was initiated producing females sired by Line 1 bulls out of CGC dams. These ½-Hereford females are being bred to Line 1 bulls and the resulting ¾-Hereford female progeny will be genotyped and those females that are heterozygous for markers flanking the gene causing white-face will be retained. In future years, the selected ¾-Hereford females will again be bred to Hereford bulls to produce f-Hereford progeny and the cycle of genotyping and selection repeated. This process can be repeated for several generations, until the calves produced cannot be distinguished from Hereford except at the narrow region of chromosome 6 containing the causal gene for white-face. At this point, the resulting bulls and heifers will be bred to each other. One fourth of the resulting progeny are expected to have the CGC genotype for the gene causing white-face in an otherwise typical Hereford background.

Relevant Publications:

Grosz, M.D. (Bylined by Clint Peck). 1998. How will molecular DNA markers affect the cattle industry? Montana Farmer-Stockman. 8-11.

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

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

Grosz, M.D. and R.T. Stone. 1999. A single nucleotide polymorphism in the bovine kit oncogene (Hardy-Zuckerman 4 feline sarcoma viral (v-kit) oncogene homolog). Animal Genetics 30:394.

Finding QTL for Carcass Traits

M.D. MacNeil, M.D. Grosz, and L.B. French

Problem: Genetic marker maps allow us to identify quantitative trait loci (**QTL**) affecting traits of economic importance. Once identified, QTL can be used to significantly increase the rate of genetic improvement through implementation of marker assisted selection. Some traits are difficult and(or) expensive to measure, are lowly heritable, occur late in life, or are determined postmortem. For these, marker assisted selection may substantially increase the rate of response relative to selection based on expected progeny differences or observed traits alone. Application of marker assisted selection by elite breeders of beef cattle seed-stock has the potential to significantly increase both the efficiency of production and the quality and desirability of the end product.

Procedures: The experimental populations were initiated with the production of F_1 bulls by mating Line 1 Hereford bulls to a Composite Gene Combination (**CGC**) cows. The resulting F_1 bulls, #94574 and #94730, were then bred by artificial insemination (**AI**) and natural service to Line 1 and CGC dams to produce progeny in 1996 (n = 146) and 1997 (n = 112), respectively.

Calves were born between March 19 and May 7 in 1996 and between March 19 and May 9 in 1997. After weaning at about 180-days of age, the calves were returned to native range pastures and were supplemented with 1.5 lbs per head per day of both barley cake and alfalfa pellets. In mid-January, the calves were removed from the range and were fed silage and chopped hay to achieve anticipated gains of 1.1 to 1.8 lbs per day. In late April, the calves were again returned to native range where they grazed until August. Subsequently, the calves were moved to an individual feeding facility equipped with electronic feeding gates. Beginning in October, after an adjustment period, the calves were individually fed a mixed ration containing 56% corn silage, 42% barley grain, 2% protein supplement on a dry matter basis. This ration contained an estimated 2.7 Mcal metabolizable energy and 11% crude protein.

Before initiating harvest, all steers and heifers were randomly assigned to a slaughter date. Beginning January 7 and weekly thereafter, six steers and six heifers were transported to a local abattoir and slaughtered using standard industry procedures. Hot carcass weight was measured the day of slaughter and other carcass measures were taken after 48 hours of storage at 35°F.

All carcass traits were adjusted for effects of year of birth (1996 or 1997), breed of dam (Line 1 or CGC), sex (heifer or steer), and all possible interactions. Three endpoints: constant age, constant live weight, and constant fat depth were derived statistically.

A panel of 170 microsatellite markers, spanning the genome, was identified and each animal genotyped. Genome maps were then constructed using data from both families combined and QTL were positioned within each sire family relative to the known marker locations. A QTL was declared to exist when it was identified in the first family and confirmed in the second family.

Findings: Shown in Figures 1 and 2 are maps of QTL effects on age-constant live weight and marbling, respectively.

The maximum QTL effect on age constant live weight was located at 52 cM on BTA 17. In both families, the effect of the QTL was similar with progeny receiving the allele from Line 1 being approximately 53 lbs lighter at harvest than those receiving the allele from CGC. The 95% confidence interval for the location of this effect spanned the interval from 35 to 69 cM. The magnitude of this QTL was markedly reduced when live weight was adjusted to the constant fat depth endpoint.

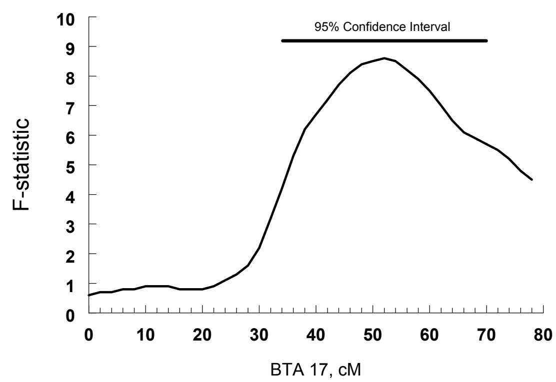


Figure 1. Effect (F-statistic) of QTL on chromosome (BTA) 17 influencing live weight at harvest.

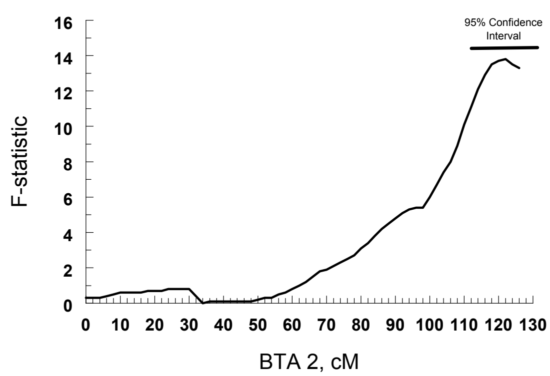


Figure 2. Effect (F-statistic) of QTL on chromosome (BTA) 2 influencing marbling.

The maximum QTL effect on age constant marbling score was located at 122 cM on BTA 2. In both families, the effect of the QTL was similar with progeny receiving the allele from Line 1 having approximately 0.6 score units less marbling at harvest than contemporaries receiving the allele from CGC. The 95% confidence interval for the location of this effect spanned the interval from 112 to 132 cM. This QTL for marbling is coincident with a QTL for birth weight that was previously identified. This QTL was also observed when the phenotypic data were adjusted to a constant live weight or fat depth.

These results pertain to alleles that segregate in crosses between Line 1 Hereford and the CGC composite. To be useful in marker assisted selection, alleles with important effects that segregate within a population must be identified. The present results provide an indication of locations that may be useful in marker assisted selection programs, but segregation of alleles with important effects at these locations within Line 1 and CGC must be established first.

Discovering regions of the genome in which QTL that affect economically relevant carcass traits are segregating provides a foundation for localizing these QTL and identifying closely linked markers. When they are identified, these closely linked markers can be used in marker assisted selection to supplement traditional progeny testing for genetic improvement of carcass attributes.

Future Directions: To be truly useful, the regions containing the QTL identified in this research need to be narrowed. These QTL should also be evaluated within both Line 1 and CGC to determine if they can be used in selection within either population. Future experiments will focus on identifying QTL for sensory attributes, growth and feed efficiency in this resource population. We also plan to examine a Wagyu x Limousin population for QTL affecting growth and carcass composition and to evaluate QTL affecting sustained reproductive performance within CGC.

Relevant Publications:

Grosz, M.D. and M.D. MacNeil. 2001. Putative quantitative trait locus affecting birth weight on bovine chromosome 2. J. Anim. Sci. 79:68-72.

MacNeil, M.D. and M.D. Grosz. 2002. A genome-wide scan for QTL affecting carcass traits at constant fat depth in a Hereford x composite double backcross population. Proc. West. Sec. Am. Soc. Anim. Sci. 53:132-134.

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

Issues in Sampling to Conserve Genetic Diversity within Breeds

M.D. MacNeil, C.K. Kealey, W.L. Lamberson, B.L. Golden, L.B. French, and H. Blackburn

Problem: Cryogenic conservation programs seek to maximize genetic diversity in the conserved sample of germplasm. Breed associations record and maintain extensive pedigree and performance databases for a wide variety of livestock populations. Until recently, genetic characterization of beef populations has been widely accomplished by estimating additive genetic differences in phenotypes within and between breeds. These methods depend on knowledge of pedigree and accurate measurement of phenotype. More recent application of techniques from molecular biology to livestock species provides an opportunity to quantify differences among these populations based directly on measures of genetic variability.

Procedures: In the first study, a list of candidates for cryogenic preservation and their pedigrees were assumed to be known. Coefficients of relationship (**R**) among the candidates were then calculated. For large numbers of candidates, one suitable approach is to generate a list of "pseudo progeny" from all possible pairs of candidates and compute the inbreeding coefficient for each of them. The R for each pair of candidates is then twice the inbreeding coefficient of their pseudo progeny. The R can be used directly as follows. The algorithm is initiated with an arbitrary animal or a set of preselected animals (perhaps ones that already have pools of semen available) and sequentially selects the animal with the lowest cumulative relationship to the previous set until a desired complement is attained.

This procedure was tested on a simulated set of relationships among 100 animals. Repeated sets of 10 animals were chosen from the population by three methods: 1) random sampling; 2) use of the algorithm initiated with a random seed animal; and 3) use of the algorithm initiated with a set of five random seed animals.

In the second study, three identifiable populations of cattle were used. They are the Line 1 (**L1**) and Prospector (**CSU**) lines of Hereford cattle and a stabilized composite consisting of 50% Red Angus, 25% Charolais, and 25% Tarentaise germplasm (**CGC**). A panel of microsatellite markers was identified for use in calculating genetic distance based on genotype. The selected markers were separated by at least 50 cM (i.e., they were not linked to each other) and spanned all 29 autosomal chromosomes. No more than two markers were on any one chromosome.

Allele frequency was computed for each microsatellite in all the three populations. Average heterozygosity and genotypic frequencies were compared with Hardy-Weinberg expectations. Estimates of the unbiased genetic distances between all pairs of populations based on all loci were calculated and the populations were clustered using the unweighted pair-group method with arithmetic averaging.

Findings: Using the pedigree-based procedure outlined above, the mean of the relationships among individuals selected for cryogenic preservation were 0.102, 0.067, and 0.076, for the three procedures, respectively. Numerically greater average relationship coefficients indicate selection of animals that are less genetically diverse than those with lesser average relationship. Thus, using the algorithmic approach based on pedigree resulted in a broader sample of the population than sampling at random. Preselection of a portion of the germplasm being sampled had little effect on the genetic diversity of the entire sample when 50% of the animals sampled were chosen based on the relationships among them.

Number of alleles per locus was greatest in CGC, as might be expected given its relatively recent origin from three diverse breeds. There were, on average, fewer alleles per locus in L1 than in CSU as might also be anticipated given the maintenance of L1 as a closed population and recent outcross matings in CSU.

Genetic distances between CGC and CSU, CGC and L1, and CSU and L1 were 0.249, 0.421, and 0.206, respectively. Before starting the research, we thought CSU and L1 would be substantially more closely related to each other than either was to CGC. However, finding CSU was nearly equidistant between L1 and CGC is suggestive of substantial genetic variability within the Hereford breed and indicative of the breadth of sampling that will be needed to preserve the genetic diversity of a breed, such as Hereford.

Future Directions: We need to first establish the degree to which pedigree-based procedures reflect direct measures of genetic diversity. Provided there is good agreement between the approaches, the pedigree-based procedures will be scaled up for sampling among members of breeds.

Relevant Publications:

Kealey, C.G., M.D. MacNeil, and B.L. Golden. 2002. Genetic distance between a multi-breed composite and two inbred lines of Hereford cattle. Proc. West. Sec. Am. Soc. Anim. Sci. 53:127-131.

MacNeil, M.D., W.R. Lamberson, and B.L. Golden. 2001. Identification of germplasm for preservation from pedigreed populations. J. Anim. Sci. Suppl. 79 (Suppl. 1):11.

Genetic Variation in Caribou and Reindeer

M.A. Cronin, J.C. Patton, N. Balmysheva, and M.D. MacNeil

Problem: Caribou and reindeer occur across arctic and sub-arctic North America and Eurasia in wild and domestic populations. In North America, native wild animals are referred to as caribou; and domestic animals, originating from European and Asian stock, are referred to as reindeer.

Wild caribou occur in herds that range in size from a few hundred to hundreds of thousands of animals. Numbers of animals in herds may fluctuate dramatically and there may be varying levels of migration between herds. Domestic reindeer occur in either confined herds or free-ranging herds. In western Alaska, for example, reindeer occur on large unfenced ranges where they sometimes mix with wild caribou.

There is considerable natural variation in phenotypic traits among herds of caribou and reindeer. The environmental and genetic components of these phenotypic differences have not been quantified, although they are probably due in part to local adaptations in wild herds, and selection in domestic herds. The extent to which different traits affect the likelihood of interbreeding between reindeer and caribou, and the fitness of hybrids, is not known.

There is interest in the relationship between caribou and reindeer because of the potential influence of domestic stock on the fitness of wild populations and the potential for wild caribou to contribute to the performance of domestic herds. There is also interest in the relationship among wild herds to assess the effect of immigration and emigration on demography

Our objective in this paper is to quantify genetic differentiation among reindeer and caribou herds from North America and Eurasia. Our primary focus is comparison of wild caribou and domestic reindeer in Alaska and Siberia, Russia, but we include herds from other areas for a broader geographic perspective.

Procedures: Blood and muscle samples were obtained from 19 herds of caribou and reindeer. Caribou samples included arctic Alaskan (Teshukpuk Lake, Central Arctic, Western Arctic, and Porcupine River) and Canadian (Alberta, Labrador, Newfoundland, Northwest Territories, Baffin Island, and Victoria Island) herds. Reindeer samples included domestic animals from Alaska (Haegemeister Island, Tom Gray Seward Peninsula herd, and Nunivak Island), Siberia, Russia (Wrangell Island, Pevek, and Severoevensk), Sweden, Norway, and Svalbard Island. We quantified genetic variation within herds, including the number of alleles per locus, observed heterozygosity, and expected heterozygosity and tested for linkage disequilibrium, Hardy-Weinberg equilibrium, and differentiation of allele frequencies among herds with pair-wise tests of heterogeneity. We also calculated genetic distances between each pair of herds with sample sizes greater than five. The genetic distances were used to construct a dendrogram with the unweighted pair-group method with arithmetic averaging procedure.

Findings: In our samples of caribou and reindeer there are 2 alleles at two loci, 5 alleles at two loci, and 8, 16, and 19 alleles at one locus each. Most alleles occurred across herds and geographic regions, but several alleles were restricted to Alaskan caribou. In addition, unique alleles were uncovered in the Norway herd, the Labrador and Newfoundland herds, and the Victoria Island herd.

There was also considerable allelic variation in all of the herds except the Svalbard Island reindeer. The Svalbard herd had a relatively low level of variation, particularly heterozygosity, and was fixed for one allele for five of the seven loci. There is a positive relationship between sample size on the numbers of alleles detected which may explain the relatively high number of alleles in the Alaskan caribou herds. The numbers of alleles in herds with small sample sizes are probably underestimates and there may be other rare alleles that we did not detect.

Six tests showed significant deviations from Hardy-Weinberg equilibrium. In all these cases, there were fewer observed heterozygotes than expected. All other herd/locus tests were in Hardy-Weinberg equilibrium.

The pair-wise tests of heterogeneity between the three Alaskan caribou herds with adequate sample sizes (Central Arctic, Western Arctic, and Porcupine River) showed no significant differences in allele frequencies between herds for all seven loci combined. Comparisons of individual loci between the Alaskan caribou herds indicate a significant difference in allele frequency for only one locus between the Western Arctic and Porcupine River herds. There were no significant differences in allele frequency for all seven loci combined, or for any individual locus, between the three Alaskan reindeer herds. Comparisons of the Alaskan caribou with the Alaskan reindeer herds showed highly significant allele frequency differences for all seven loci combined, and for 35 of 54 (65%) of the pairwise herd comparisons of individual loci. The Alaskan reindeer and Russian reindeer allele frequencies were also highly significantly different for all seven loci combined, and for 11 of 18 (61%) of the pairwise comparisons of individual loci. The genetic distances between herds and the dendrogram (Figure 1) resulting from them show several important divisions. First, the three Arctic Alaska caribou herds cluster together, within a larger cluster containing the Arctic Canadian caribou herds. Second, the eastern Canadian caribou (Newfoundland and Labrador) occur in separate clusters from the other caribou. Third, the Alaska reindeer and Russian reindeer occur in a cluster, separate from caribou and Scandinavian reindeer. The means of the pair-wise herd genetic distances (**D**) reflect these clusters: between Alaska caribou herds D = 0.1823; between Alaska reindeer herds D = 0.1863; between Alaska reindeer and Russian reindeer herds D = 0.2383; between Alaska reindeer and Alaska caribou herds D = 0.3277; and between Alaska caribou and Russian reindeer herds D = 0.3553. Although the Alaska reindeer and Russian reindeer have significantly different allele frequencies for several loci, the overall genetic distance is less than the distance between the Alaska reindeer and Alaska caribou. The same microsatellite alleles occur across the range of *Rangifer* suggesting there are no major phylogenetic divisions within the species, although there is differentiation of allele frequencies between herds of caribou and reindeer.

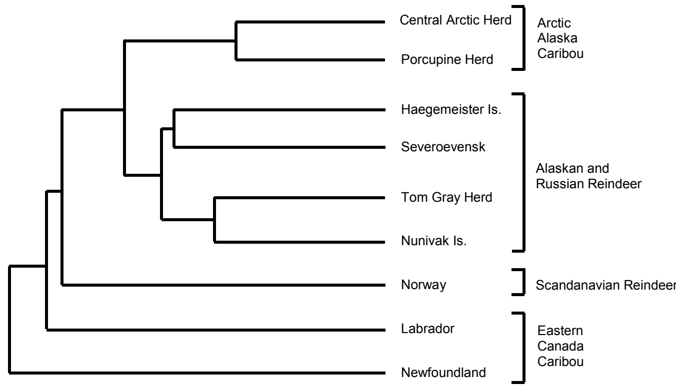


Figure 1. Dendrogram illustrating the genetic distances between herds and their geographic distribution.

The Central Arctic, Western Arctic, and Porcupine River Alaska caribou herds are not genetically differentiated from each other. Although studies of marked females indicate that the herds are generally segregated on calving ranges, they frequently mix on breeding and winter ranges. The genetic data are consistent with field observations that suggest there is interbreeding of animals from different calving ranges (i.e., herds) and that the herds collectively comprise one population. The situation is different in the southern Yukon Territory, Canada, where caribou herds are segregated on winter ranges and genetically differentiated. Similarly, there are significantly different allele frequencies in Alaska reindeer and caribou. Our data suggest limited gene flow between domestic reindeer and wild caribou herds.

Future Direction: Genomic technologies can be used to objectively assess biodiversity and thus impact natural resource management. However, we do plan for further studies in this area, at the present time.

Relevant Publications:

Cronin, M.A., J.C. Patton, N. Balmysheva, and M.D. MacNeil. 2002. Genetic variation in caribou and reindeer (*Rangifer tarandus*). Animal Genetics. (accepted 3 July 2002).

Cronin, M.A., J.C. Patton, and M.D. MacNeil. 2002. Genetic variation in domestic reindeer and wild caribou (*Rangifer tarandus*). Proc. West. Sec. Am. Soc. Anim. Sci. 53:138-141.

Effects of Sire Misidentification on Estimates of Genetic Parameters for Birth Weight and Weaning Weight of Hereford Cattle

S. Senneke, L.D. VanVleck, and M.D. MacNeil

Problem: Misidentification of sires may be a weakness in selection programs in the cattle industry. Studies have shown in dairy cattle that sire misidentification can decrease estimates of heritability and cause an incorrect ranking of sires. In beef cattle, Lee et al. (1997) observed decreases in both direct and maternal heritability estimates decrease with increased sire misidentification. In addition, sire misidentification may cause the estimate of a negative direct-maternal genetic correlation to become positive. Effects of misidentification on genetic correlations among traits are unknown.

With the possibility of sire misidentification, one question is which model is best for estimating genetic parameters. One of the most common animal models used in beef breeding includes fixed effects of year, sex, age of dam, and their interactions and random effects of direct genetic and maternal genetic effects, a fixed covariate of Julian birth date, and an uncorrelated random effect of permanent environmental effect of the dam. Another potential source of variation is sire x year interaction effects. A specific question is which model would more accurately estimate genetic parameters from data with sire misidentification, a model with or a model without sire by year effects?

Procedures: Data used were from Line 1 Herefords collected from 1935-1989 at Fort Keogh. Data were available on a total of 4,291 animals. There were 4,155 records available for birth weight analyses and 3,884 records available for weaning weight analyses. Sire identification was randomly assigned incorrectly at rates of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50% to each calf crop. The incorrect sire identification was that of another bull producing calves that same year. Assignment of identification to the incorrect sire was randomly proportional to the number of progeny the other sires had that year. One hundred random replicates for each rate of sire misidentification were obtained.

The misidentified records were then analyzed using a derivative-free algorithm to obtain **REML** estimates of variance and covariance components. Average estimates of the variance and covariance components were obtained from the 100 replicates for each rate of sire misidentification. The original data set was also analyzed using REML. The averages of estimates for the 100 replicates, for each rate of sire misidentification, were then compared to the estimates of genetic parameters from the original (assumed correctly identified) records.

Genetic parameters were estimated for both birth weight and weaning weight using two different models. Both single and two-trait analyses were performed. Model 1 included fixed effects of year by sex and age of dam, and a covariate of calendar birth date, with random effects of animal genetic, maternal genetic, maternal permanent environment, and residual. Model 2 included sire by year interaction as another random factor in addition to the factors of Model 1. Estimates from each of the 100 replicates for each misidentification rate and trait were summarized to obtain averages of the estimates of the variance components and genetic parameters. Average estimates, as well as the estimate from the original data, were then graphed to describe the pattern of effects of sire misidentification on estimates of the genetic parameters.

Results: Average estimates of both direct and maternal heritability decreased linearly as the fraction of progeny misidentified increased for both models for birth weight and weaning weight. Average estimates of the direct-maternal genetic correlation increased as the fraction of progeny misidentified increased for both models for birth weight and

Table 1. Comparison of average estimates of genetic parameters with single trait and two-trait analyses with no misidentification and with 50% misidentification

		Single trait analyses				Two-trait analyses			
		Model 1		Model 2		Model 1		Model 2	
Weight	Parameter[a]	No	50%	No	50%	No	50%	No	50%
Birth	h^2	0.36	0.12	0.36	0.11	0.35	0.18	0.35	0.18
	m^2	0.14	0.10	0.14	0.10	0.14	0.10	0.14	0.10
	r_{am}	-0.06	0.78	-0.06	0.81	-0.07	0.47	-0.05	0.54
	c^2	0.03	0.05	0.03	0.05	0.03	0.05	0.03	0.05
	s^2	-	-	0.00	0.00	-	-	0.01	0.01
	σ^2	18.1	17.3	18.1	17.3	18.1	17.5	18.1	17.6
Weaning	h^2	0.20	0.03	0.17	0.03	0.21	0.10	0.21	0.10
	m^2	0.16	0.05	0.15	0.105	0.15	0.07	0.15	0.07
	r_{am}	-0.38	0.38	-0.31	0.50	-0.39	-0.19	-0.39	-0.20
	c^2	0.19	0.27	0.19	0.27	0.19	0.25	0.19	0.25
	s^2	-	-	0.02	0.00	-	-	0.00	0.00
	σ^2	532.0	509.0	531.0	510.0	537.0	524.0	537.0	525.0

[a] Parameters: h^2 = direct heritability, m^2 = maternal heritability, r_{am} = direct-maternal genetic correlation, c^2 = proportion of phenotypic variance due to maternal permanent environmental effects, s^2 = proportion of phenotypic variance due to sire by year interaction effects, and σ^2 = phenotypic variance (kg^2).

weaning weight. Model 2 caused average estimates to be slightly less for direct and maternal heritability and slightly greater for estimates of the direct-maternal genetic correlation than Model 1. Sire by year interaction effects had more of an impact on average estimates of genetic parameters for weaning weight than for birth weight. Table 1 compares the estimates of genetic parameters from the original data with the average estimates of genetic parameters with 50% misidentification.

In addition to the single trait analyses, correlations between birth weight and weaning weight were estimated with two-trait analyses. The average estimate of the correlation between direct effects of birth weight and weaning weight increased slightly with sire misidentification. The average estimate of the correlation between the maternal effects of birth weight and weaning weight decreased slightly with misidentification. Table 2 compares the estimates of the correlations from the original data with the average estimates of the correlations with 50% sire misidentification.

Table 2. Correlations[a] between birth weight and weaning weight with no misidentification and with 50% misidentification of sires

	Model 1		Model 2	
	No	50%	No	50%
r_{a1a2}	0.63	0.76	0.66	0.82
r_{a1m2}	-0.21	-0.21	-0.23	-0.25
r_{a2m1}	0.16	0.57	0.14	0.60
r_{m1m2}	0.23	0.14	0.25	0.11

[a]Correlations:

r_{a1a2} = genetic correlation between direct birth weight and direct weaning weight,

r_{a1m2} = genetic correlation between direct birth weight and maternal weaning weight,

r_{a2m1} = genetic correlation between direct weaning weight and maternal birth weight,

r_{m1m2} = genetic correlation between maternal birth weight and maternal weaning weight.

Results indicate that sire misidentification biases estimates of genetic parameters. Estimates of the direct and maternal genetic correlations between birth weight and weaning weight were less biased than estimates of the direct and maternal heritabilities. Ignoring sire by year interaction effects increased estimates of both direct and maternal heritability and decreased estimates of direct-maternal genetic correlation. Sire misidentification will also decrease genetic gain from selection due to bias in prediction of breeding values. Emphasis on correct sire identification will improve reliability of estimates of genetic parameters and will also increase response to selection.

Future Directions: We continue to collaborate with faculty members at a variety of universities in the training of graduate students. Typically data from a project conducted at Fort Keogh Livestock and Range Research Laboratory is the basis for the student's work on a specific problem of mutual interest. These collaborations expand our scope and capability for research into important questions relevant to genetic improvement programs.

Relevant Publications:

Senneke, S.L. 2002. Effects of sire misidentification on estimates of genetic parameters for birth weight and weaning weight in Hereford cattle. M.S. Thesis, University of Nebraska, Lincoln.

Geldermann, H., U. Pieper, and W.E. Weber. 1986. Effect of misidentification on the estimation of breeding value and heritability in cattle. J. Anim. Sci. 63:1759-1768.

Citations:

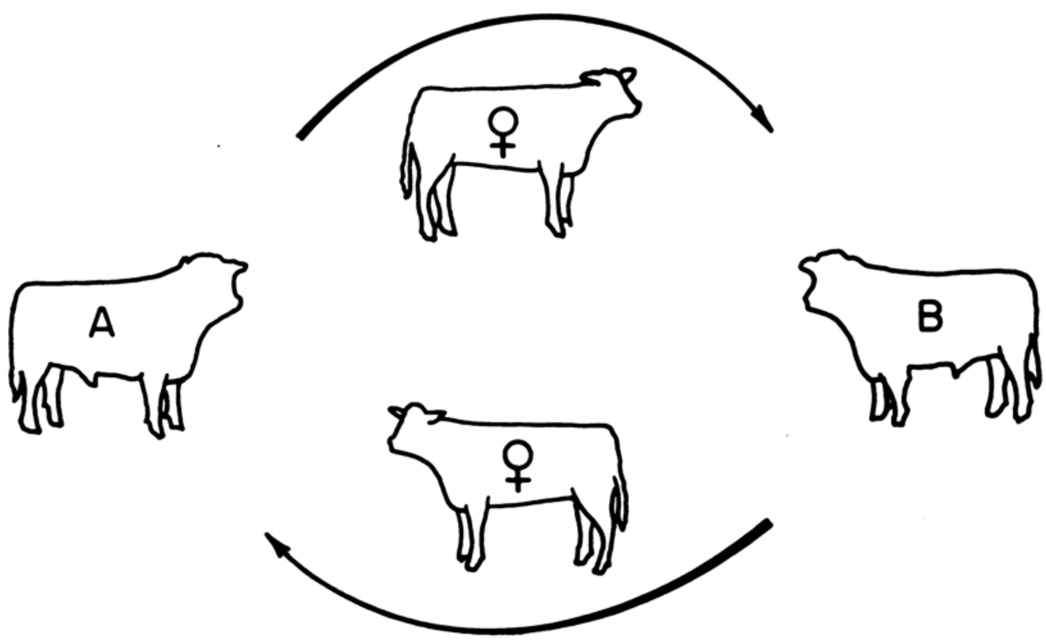
Lee, C. and E.J. Pollak. 1997. Influence of sire misidentification on sire x year interaction variance and direct-maternal genetic covariance for weaning weight in beef cattle. J. Anim. Sci. 75:2858-2863.

E. Breeding Systems

Genetic options that are available to producers to enhance production efficiency run the gamut from selection within a breed to systematic use of different breed resources in crossbreeding.

Improvement is made by selecting animals for breeding that are above average in genetic merit for the production traits of interest. The most accurate selection decisions are made through the use of estimated progeny differences (**EPD**), when they are available. Unfortunately, EPDs are not available for all economically important traits and breeders are compelled to rely on records of individual animals and their intuition. Selection decisions are further complicated by the fact that improving profit is a function of multiple traits. All too often selection decisions based on one or a few traits, produce unintended detrimental responses in other traits that were ignored in the process.

Commercial producers can also use genetic variation that is not highly heritable to improve production efficiency. 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 weaknesses and mate them in ways that maximize expressed heterosis.



Effects of Hypermuscularity on Beef Production

M.D. MacNeil, R.E. Short, 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% 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 breeds with high genetic potential for depositing lean tissue. This genetic potential for depositing lean may be achieved in two ways. First, in some breeds of cattle, selection has favored alleles for leanness at many loci that individually have small effects. European breeds such as Limousin, Charolais, or Maine-Anjou may have achieved their genetic potential for lean tissue deposition primarily by this mechanism. Second, alternative alleles of a single gene (myostatin), can cause dramatic differences in muscling. Breeds such as Piedmontese and Belgian Blue have, in high frequency, myostatin alleles that confer hypermuscularity or double muscling. Calves sired by these breeds may have leaner carcasses compared with calves sired by less extreme breeds. Using breeds with greater potential for lean tissue deposition has potential for immediately improving composition without using drugs or implants.

In this research, our objectives were to: 1) characterize breeds of similar mature size that were presumed to differ in the underlying genetic mechanism conferring muscularity; and 2) elucidate effects of alternative alleles at the myostatin locus on growth, carcass, and reproductive traits.

Procedures: Crossbred cows and heifers that did not have extreme muscularity were bred by artificial insemination (**AI**) to Piedmontese (**P**), Limousin (**L**), and Hereford (**H**) bulls. These breeds were chosen because they are similar in mature size and diverse in their genetic propensity for leanness. Approximately 300 F_1 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.

Calving date, birth weight, and calving difficulty score were recorded at birth of the resulting calves. Calves were weaned at 179 days of age.

After weaning, the male calves were fed either individually or in pens of approximately 25 head. A growing ration was fed from weaning until the calves reached 850 lbs. Subsequently, they were fed a finishing ration for either 90 or 132 days. The cattle were harvested at a commercial abattoir using industry standard procedures and carcass data were collected 48-hours postmortem. After aging for 14-days, a rib steak was flash-frozen and stored for subsequent determination of shear force (tenderness).

After weaning, the female calves, were developed as replacement heifers and monitored to determine when they attained puberty. These F_1 female calves were mated to contemporary F_1 bulls with the same breed of sire to produce F_2 calves. Management and harvest of the F_2 progenies were generally similar to that of the F_1 males, except that heifers were switched to the finishing ration upon attaining 750 lbs.

Blood samples from the Piedmontese-cross F_2 animals were processed to obtain DNA. The DNA was then assayed for the presence of the myostatin mutation characteristic of Piedmontese. Genotypes were classified as having zero (P_0), one (P_1), or two (P_2) copies of the mutant allele.

Findings: *F1 calves*: Hereford-sired calves had approximately 4 days shorter gestation periods and 5 lbs lighter birth weights than either Limousin- or Piedmontese-sired calves, which were similar. However, calving difficulty was similar for Hereford- and Limousin-sired calves and 5% less frequent than for Piedmontese-sired calves.

Differences in gain were relatively small from birth to weaning, but became larger as the calves grew older. By the finishing phase, both Limousin- and Hereford-sired calves had 0.3 lbs/day greater average daily gains than Piedmontese-sired calves. Differences among breeds of sire in feed intake were relatively small.

Carcass weights of Limousin- and Piedmontese-sired calves were 17 lbs greater than those of Hereford-sired calves. Ribeye area was least and fat depth was greatest in Hereford-sired calves. Conversely, ribeye area was greatest and fat depth was least in Piedmontese-sired calves. Limousin-sire calves were intermediate for both traits. Piedmontese-sired calves had less kidney, pelvic, and heart fat than either Hereford- or Limousin-sired calves. These differences in carcass traits resulted in a clear stratification of USDA Yield Grade (**YG**) with Piedmontese-sired calves being 1.1 YG lower than Hereford sired calves and 0.7 YG lower than Limousin-sired calves.

Hereford-sired calves had nearly ½ score (1 score = e.g., the difference between small and slight with larger scores indicating greater marbling) more marbling than the progenies of Limousin and Piedmontese sires, which were similar. However, shear force was 0.7 lbs less for steaks from calves sired by Piedmontese bulls than for Hereford- or Limousin-sired contemporaries.

Hereford- and Piedmontese-sired heifers were younger at attainment of puberty by 23 days and 38 days, respectively, than Limousin-sired heifers. The difference in age at puberty between Hereford- and Piedmontese-sired heifers was not significant.

F2 calves: Survival of P_2 calves was lower than expected based on genotypic frequencies. This may indicate some natural selection against the P_2 genotype.

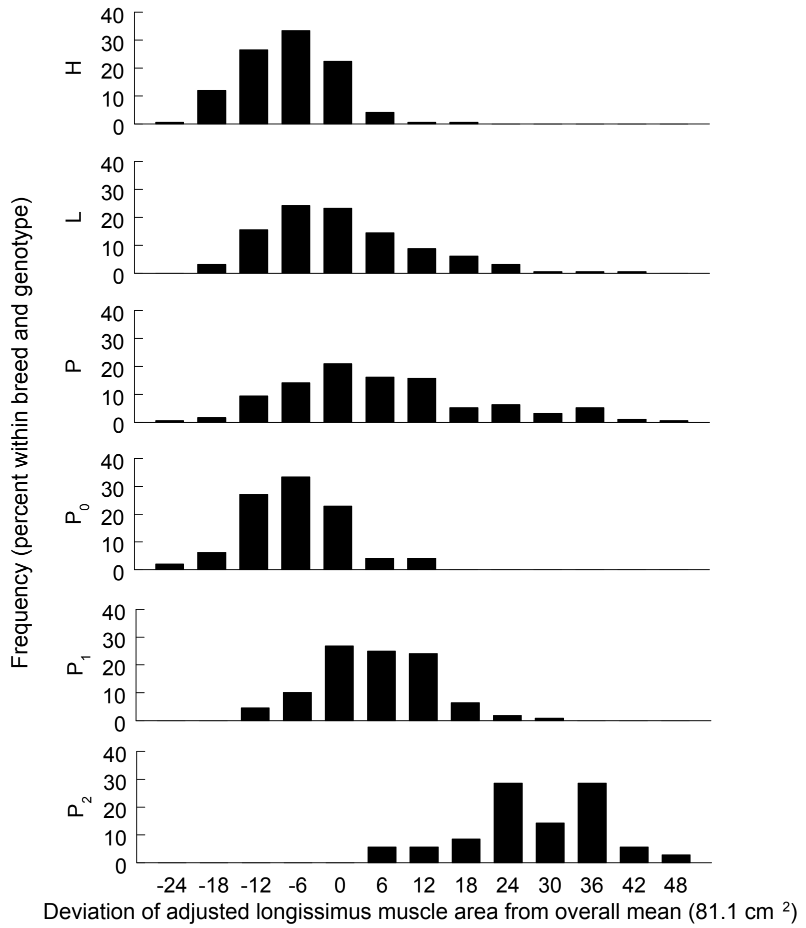


Figure 1. Frequency distributions for ribeye (longissimus) area by genetic group of F_2 progeny.

The ½-Hereford calves were lighter at birth and at weaning than their ½-Limousin contemporaries. However, calving difficulty for both groups was similar. There were no differences between ½-Hereford and P_0 ½-Piedmontese calves in birth or weaning traits. The P_0 calves were lighter and born with less difficulty that P_2 calves.

Live weight at harvest was similar for all five genotypes. However, differences in dressing percentage resulted in ½-Hereford and P_0 calves having the lightest carcasses, with ½-Limousin and P_1 calves intermediate, and P_2 calves having the heaviest carcasses. Ribeye area followed a similar trend (Figure 1). The ½-Hereford calves had the greatest fat depth, then ½-Limousin, followed in order by P_0, P_1, and P_2, with P_2 having the least fat depth. Differences among genotypes in USDA Yield Grade followed a trend similar to fat depth.

The ½-Limousin progeny had less marbling than ½-Hereford calves which were similar to the P_0 calves. The P_1 calves were similar in marbling to ½-Limousin calves and their P_2 contemporaries had less marbling than any of the other genetic groups. However, tenderness as measured by the Warner-Bratzler shear was similar across all genetic groups.

Efficiency of live weight gain was not affected by the genotypes evaluated. However, when adjusted to a primal cut-basis, the ½-Limousin and P_2 progenies were most efficient.

Thus, Hereford-based production systems produce high-quality beef with few associated problems and are adaptable to a wide range of conditions. Increased production of lean beef can be accomplished by using breeds such as Limousin and Piedmontese as terminal sires.

Future Direction: This project has been completed and no further investigations along this line are currently planned.

Relevant Publications:

Grings, E.E., R.E. Short, M.D. MacNeil, R.A. Roeder, and M.J. Roeder. 2001. Interactions in postweaning production of F_1 cattle from Hereford, Limousin, or Piedmontese sires. J. Anim. Sci. 79:317-324.

MacNeil, M.D., R.E. Short, and E.E. Grings. 2001. Characterization of topcross progenies from Hereford, Limousin, and Piedmontese sires. J. Anim. Sci. 79: 1751-1759.

Short, R.E., M.D. MacNeil, M.D. Grosz, D.E. Gerrard, and E.E. Grings. 2002. Pleiotrophic effects in Hereford, Limousin, and Piedmontese F_2 crossbred calves of genes controlling muscularity including the Piedmontese myostatin allele. J. Anim. Sci. 80:1-11.

Can Balancing Birth Weight and Growth Enhance Beef Production?

M.D. MacNeil

Problem: Genetic selection to increase production tends to decrease net reproduction. Improving more than one unfavorably correlated trait 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-olds 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 first being observed in labor were assisted in delivering the calf.

Crossbred cows were bred by artificial insemination (**AI**) using semen collected from bulls used in Line 1 before the sublines were established and from bulls with generation numbers between three and four of both sublines. The resulting topcross progeny were evaluated for growth, feed intake, and carcass traits to determine correlated responses to selection.

Throughout the course of this selection experiment the Line 1 Hereford cows were weighed before calving, at the beginning and end of the breeding season, and at weaning. Mathematical models describing growth in biologically relevant terms were fit to these weights. As a result, parameters describing mature size, maturing rate, and birth weight relative to mature size were derived.

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 expected from the difference in selection applied. Maternal genetic effects were similar and nearly constant in both YB and YW. The nearly 20 lb reduction in genetic response in 365-day weight of YB compared with YW is the cost of limiting birth weight.

Estimated direct and maternal heritabilities for calving ability were 0.31 and 0.04, respectively. Thus, it appeared the genetic control of calving ability was more nearly a trait of the calf than a trait of the dam, consistent with the hypothesis that the calf's birth weight is the primary determinant of calving difficulty.

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.

Progeny Test Results: Average breeding values for birth weigh, based on topcross progeny, of YB sires were less than for YW sires and had decreased relative to the base generation (**BS**). This result occurred despite breeding values for gestation length being greater for YB sires than for either YW or BS sires. Breeding values for 180-day weaning weight were greater for YW sires than for either YB or BS sires.

During the backgrounding and finishing phases, performance of progeny of YB and YW sires resulted in their breeding values for growth rate being similarly greater than BS sires. Breeding values for feed efficiency suggested YB sires had greater genetic potential for efficient growth than YW sires.

The primary source of divergence between sublines in carcass attributes stems from the apparent increase in genetic potential for fatness in YB sires and a corresponding reduction in YW sires relative to BS sires. Differences in shear force (tenderness) paralleled those observed in marbling.

Basing selection decisions on easily and routinely measured growth traits, while achieving the intended direct responses, may not favorably impact all components of production efficiency. The correlated increases in fatness observed in this progeny test provide one such example.

Effects on characteristics of cows: Mature size of females increased in both the YB and YW sublines in response to the selection applied. However, response in YB was only 80% of that observed in YW.

It seems birth weight increased similarly as a fraction of mature size in both the YW and YB sublines. This may help explain the lack of improvement in calving ability in response to selection for below average birth weight and high yearling weight that was observed earlier.

Breeding values for mature weight indicated YB would be genetically earlier maturing that YW at the conclusion of the experiment. The usual expectation is that earlier maturing cattle are fatter at a constant age which was confirmed by the YB sires having greater breeding values for fatness based on the progeny test results shown previously.

Genetic trends in maternal breeding values were used to indicate differences in milk production of the cows. A clear pattern of divergence between sublines emerged during the later years of this experiment, with the maternal effect being greater in YW than in YB. Based on this result and the relationship between maternal breeding value and actual milk production, it seems that genetic potential for milk production may have increased 52% more rapidly in YW than in YB.

Taken together, the preceding results suggesting earlier maturity and reduced energy requirements resulting from smaller mature size and less milk production of cows the YB subline may increase biological efficiency and sustainability in some production systems, relative to cows of the YW subline.

Future Direction: This research has been completed and the results published over the past three years. Portions of the results will provide the basis for a new evaluation of multiple-trait selection indexes for Hereford cattle.

Relevant Publications:

MacNeil, M.D. and T.B. Mott. 2000. Using genetic evaluations for growth and maternal gain from birth to weaning to predict energy requirements of Line 1 Hereford beef cows. J. Anim. Sci. 78:2299-2304.

MacNeil, M.D., R.E. Short, and J.J. Urick. 1999. Progeny testing sires selected by independent culling levels for below-average birth weight and high yearling weight or by mass selection for high yearling weight. J. Anim. Sci. 77:2345-2351

MacNeil, M.D., J.J. Urick, and G. Decoudu. 2000. Characteristics of Line 1 Hereford females resulting from selection by independent culling levels for below-average birth weight and high yearling weight or by mass selection for high yearling weight. J. Anim. Sci. 78:2292-2298.

MacNeil, M.D., J.J. Urick, and W.M. Snelling. 1998. Comparison of selection by independent culling levels for below average birth weight and high yearling weight with mass selection for high yearling weight in Line 1 Hereford cattle. J. Anim. Sci. 76:458-467.

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Validation of EPDs (Expected Progeny Differences)

M.D. MacNeil

Problem: Influential breeders sometimes express the opinion that "EPDs are not accurate enough for us to use as a selection tool." Even more often someone will ask, "Does a milk EPD really predict differences in milk production?" Or, "Will the calves of a low birth weight EPD bull really have light birth weights?"

For a trait like birth weight that can be measured directly, the process may seem straightforward. Actual observations, birth weights of calves, are analyzed to remove the effects of other factors (e.g., age of dam, sex of calf, year, and ranch) that are known to also affect birth weight. The remaining variation is partitioned into genetic effects (**EPD**s) and according to the laws of Mendelian inheritance and effects which cannot otherwise be ascribed. However, the milk EPD is more difficult to grasp. Clearly, only on very rare occasions, as in a research setting, is milk production of beef cows measured directly. Rather than relying on measured milk production, the milk EPD results from dividing observed weaning weight into components due to the calf expressing its growth potential and its dam creating a favorable environment (milk) for growth.

In any case, the EPDs are the end result of complex mathematical analysis. Further, EPDs are predicted such that only the differences between animals are relevant. The numerical value of an EPD does not predict future observations. This complex process and the form of the results create innate distrust of the results. Therefore, the objective of the research reported here was to determine if differences in EPD do, in fact, predict differences in performance. We will consider the two most frequently questioned EPD, those for birth weight and milk.

Procedures: Twenty-six Hereford bulls were progeny tested by mating them to crossbred cows in several projects. These projects occurred from 1993 to 1996 creating a number of different contemporary groups. Birth weights were routinely recorded at calving the following year. Birth weight EPD were calculated independently of these progeny test data.

Milk production can be measured in beef cattle using the weigh-suckle-weigh technique. In early afternoon, calves are separated from their dams. Later that evening they are returned to their dams and allowed to nurse. This nursing is to empty the cows udder of milk. The calves are again separated from their dams and they remain apart for 12 hours.

The next morning, the calves are weighed, reunited with their dams and allowed to nurse until no more milk is available, then quickly weighed again. The difference in each calf's weight before and after nursing is a measure of its dam's milk production.

In this research, milk production by Line 1 Hereford cows was measured four times during lactation. Characteristics of the calves at each time of measurement are shown in Table 1. The first measurement was taken shortly before the beginning of the breeding season and the last measurement was collected at weaning. There were records from 76 cows 2 years old, 83 cows 3 years old, 59 cows 4 years old, and 113 cows 5 years old and older.

Table 1. Age and weight of Line 1 Hereford calves when weigh-suckle-weigh records of milk were collected

	Age, days			Weight,
Measurement	Average	Oldest	Youngest	lbs
1	52	87	9	179
2	93	132	53	250
3	137	180	93	332
4	180	215	137	399

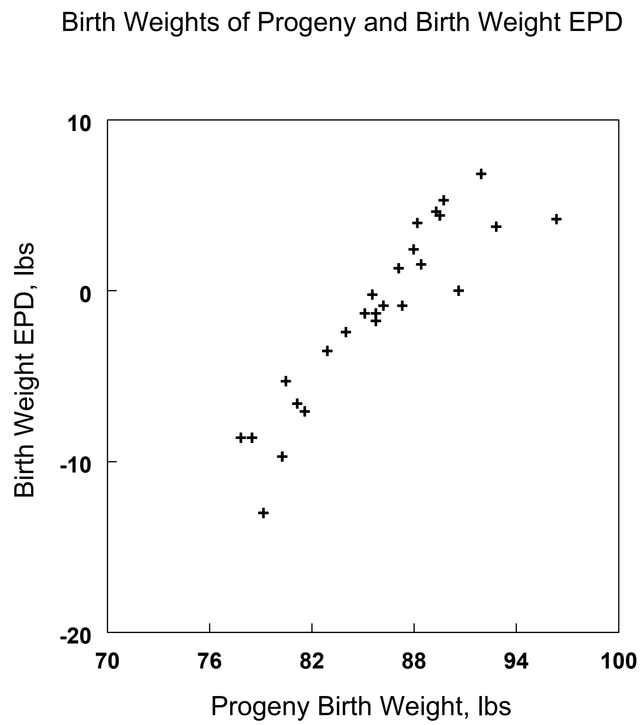


Figure 1. Illustration of the relationship between birth weight EPD and actual birth weights of progeny sired by Hereford bulls.

A mathematical model of a lactation curve was fit to the resulting milk production records. The milk EPD was added to this general model, thus allowing different lactation curves for cows with different milk EPD.

Findings: *Birth Weight:* Shown in Figure 1 is the scatter plot of the EPD for birth weight against the observed progeny birth weights for 26 Hereford sires. The positive relationship between the EPD and the progeny performance is obvious. However, it is also noteworthy that the EPD are not perfect. For example, at an EPD of approximately +4 the range in average birth weights of the progeny is from about 88 to 96 lbs. This imperfection is expected as both the EPD and progeny average are derived from limited amounts of data and are thus subject to sampling variation.

Milk: Shown in Table 2 are estimates of peak and total milk yields for various levels of milk EPD. The milk EPD themselves reflect differences in weaning weight of calves that presumably result from differences in milk production. Because several pounds of milk are required to produce a single pound increase in weight, differences in total milk production should be greater than differences in the milk EPD.

Table 2. Milk EPD, peak yield, and total milk production from mature Line 1 Hereford cows

Milk EPD	Peak yield, lbs./day	Total yield, lbs. /lactation
-22	11.1	1537
-11	13.0	1806
0	15.0	2072
11	16.9	2341
22	18.8	2608

Other researchers have likewise found similar close relationships between the milk EPD and total milk yield. These results, that show a 1-lb change in milk EPD corresponding to a 24-lb change in total yield, are among the most conservative. Other estimates range upward to slightly more than twice these and extend the relationship of milk EPD with milk production to additional breeds besides Hereford.

In conclusion, a close relationship exists between differences in EPD and differences in actual performance. To the extent that breeders wish to select replacements based on performance criteria, they are encouraged to use EPDs for this purpose.

Future Direction: We plan to continue working toward establishing objective criteria for genetically improving profitability and sustainability of beef production. This work includes developing new genetic evaluations for component traits that do not currently have EPD and developing combinations of EPD that will lead to greater profitability and sustainability.

Relevant Publications:

Herring, W.O. and M.D. MacNeil. 2001. An overview of the 1999. Angus sire alliance. Proc., Beef Improvement Federation. Pp. 147-157.

MacNeil, M.D. 1999. Sorting out the bulls: Using performance information to evaluate bulls–or how to interpret the data in a sale catalog. Montana Farmer-Stockman. February. p. WB36-40.

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

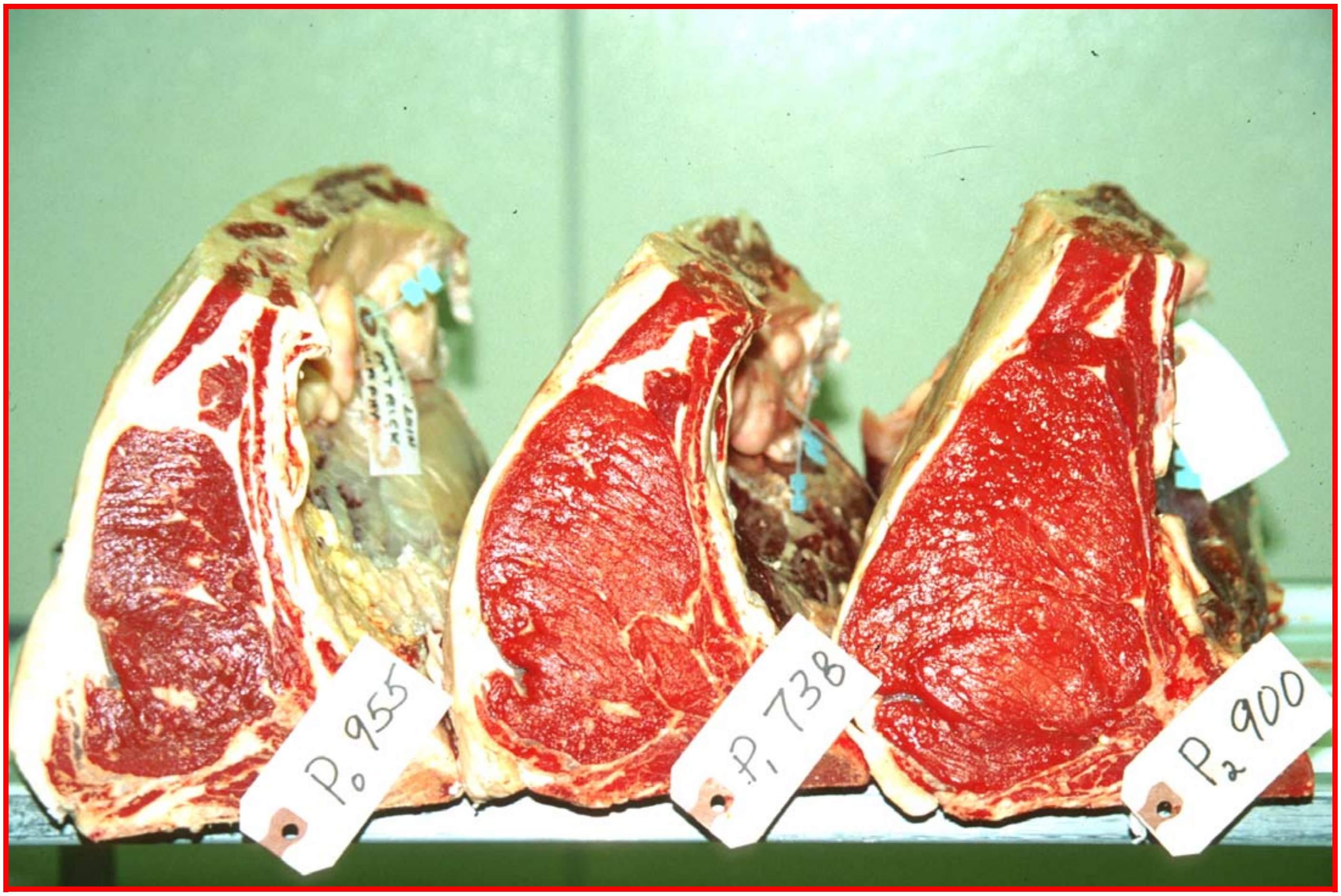
MacNeil, M.D. and T.B. Mott. 2000. Using genetic evaluations for growth and maternal gain from birth to weaning to predict energy requirements of Line 1 Hereford beef cows. J. Anim. Sci. 78:2299-2304.

MacNeil, M.D., R.E. Short, and E.E. Grings. 2001. Characterization of topcross progenies from Hereford, Limousin, and Piedmontese sires. J. Anim. Sci. 79:1751-1756.

MacNeil, M.D., R.E. Short, and J.J. Urick. 1999. Progeny testing sires selected by independent culling levels for below-average birth weight and high yearling weight or by mass selection for high yearling weight. J. Anim. Sci. 77:2345-2351.

F. Producing Lean Beef

The ultimate endpoint in the cattle industry is the production of a meat product desirable to the consumer. Beef products need to be tasty and healthful as well as competitively produced. Technologies exist throughout all phases of the beef industry to manipulate final product quality. These may range from the choice of genetics and mating systems for the range cow herd to post-harvest technologies. Marketing strategies and management of cattle within the feedlot have impacts on the quality of the final product and also influence profitability to various segments of the industry.



Interactions in Postweaning Production of F_1 Cattle from Hereford, Limousin, or Piedmontese Sires

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

Problem: Use of cattle breeds that express various degrees of muscle hypertrophy may be a way to increase production of a lean product. This trait can dramatically increase muscle size and decrease carcass fat. Management factors such as days on feed, dietary crude protein concentrations, and castration of male cattle can all impact carcass characteristics. Information was needed on the production and carcass characteristics of cattle with the potential for muscular hypertrophy and their interactions with other management strategies.

Procedures: Crossbred cows were bred by artificial insemination (**AI**) for 2 years to 22 normal muscled Line 1 Hereford sires, 24 moderate muscled Limousin sires, or 23 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 left intact or castrated at approximately 2 months of age. Calves remained with their dams until approximately 7 months of age.

After weaning, male calves were placed into covered pens having individual electronic feeding gates. Calves were fed growing diets from weaning to 850 lbs and were then individually switched to finishing diets for 90 or 132 days. Cattle were slaughtered at a commercial abattoir using standard industry procedures. Hot carcass weight was measured the day of slaughter and other carcass measures were taken after 48 hours of storage. Meat tenderness was determined on the ribeye by Warner-Bratzler shear force test.

Findings: Steers gained 0.2 lbs/day less than bulls and required 12 more days to reach 850 lbs. Feed efficiency averaged 0.012 lbs more liveweight gain per lb of feed for bulls compared with steers, while DM intake did not differ between the two. No interactions occurred between breed and gender during the growing period for growth characteristics.

Piedmontese-sired bulls finished for 132 days tended to be lighter than Hereford- or Limousin-sired bulls finished for the same length of time (Table 1). This difference averaged 66 lbs. There were no differences in slaughter weight among other gender-finishing length combinations.

Due to differences in dressing percent among breed-gender combinations (Table 2), the patterns for hot carcass weight were different from those for slaughter weight. Hot carcass weight of steers was less for Hereford- than for Limousin- or Piedmontese-sired steers which did not differ from one another, whether finished for 90 or 132 days. For bulls, length of finishing period affected the difference in hot carcass weight among sire breeds. When fed for 90 days, hot carcass weight of Piedmontese-sired bulls was greater than that of Hereford- and Limousin-sired bulls. When finished for 132 days, Hereford- and Piedmontese-sired bulls did not differ in hot carcass weight, but both had lighter carcasses than Limousin-sired bulls.

Extending the length of finishing period from 90 to 132 days had the largest impact on shear force of Hereford-sired steers, decreasing it 26% (Table 1). Piedmontese-sired bulls also exhibited a decrease in shear force with increasing length of finishing period. Increasing length of finishing period did not decrease shear force in other gender-sire breed combinations.

Piedmontese-sired bulls had less backfat than any other gender-sire breed combination, whether finished for 90 or 132 days (Table 1). Piedmontese- and Hereford-sired steers increased backfat thickness between 90 and 132 days whereas Limousin-sired steers did not. The greatest increase in backfat thickness was for Hereford-sired steers, with an increase of 0.14 inch over 42 days.

Marbling score was lower in bulls than in steers, but within gender, the ranking of sire breeds differed. For bulls, marbling score did not differ between Hereford- and Limousin-sired bulls, but these sire breeds had greater marbling than Piedmontese-sired bulls. Limousin- and Piedmontese-sired steers had less marbling than Hereford-sired steers.

Kidney, pelvic, and heart fat of bulls averaged about 71% that of steers (Table 2). This trait did not differ among sire breeds in steers, but Limousin-sired bulls had greater kidney, pelvic, and heart fat than Hereford-sired bulls, who had a greater amount than Piedmontese-sired bulls. There was also a tendency for a gender by length of finishing period interaction for kidney, pelvic, and heart fat as there was a greater difference between bulls and steers at 132 days (0.83%) compared with 90 days (0.56%) on the finishing diet.

Bulls had larger ribeye area than steers but the rankings of sire breed within gender differed (Table 2). Piedmontese-sired cattle had larger ribeye muscle area than other sire breeds, whether bulls or steers. Between Limousin- and Hereford-sired cattle, ribeye area did not differ in bulls, but was greater in Limousin- than Hereford-sired steers.

A combination of differences in fat and muscle characteristics resulted in an interaction between breed and gender for yield grade. Piedmontese-sired cattle had the lowest yield grade whether fed as bulls or steers. Limousin-sired bulls did not differ in yield grade from Hereford-sired bulls, but Limousin-sired steers had lower yield grades than Hereford-sired steers.

The comparison of the effect of sire breed on weight of primal cuts was affected by length of finishing period (Table 1). After 90 days on the finishing diet, Hereford- and Limousin-sired cattle did not differ in primal cut weights, while at 132 days Limousin-sired cattle had greater weight of primal cuts than Hereford-sired cattle. Piedmontese-sired cattle had greater primal cut weight than the other sire breeds at both finishing lengths. There was also a length of finishing period by gender interaction for primal cut (Table 1) due to a greater increase in primal weight between 90 and 132 days of finish for bulls (33 lbs) than for steers (15.2 lbs).

Average daily gain decreased with increasing time on feed (Table 3). This resulted in a decrease in efficiency of utilization of feed for gain during the last 42 days on feed. Length of finishing period had direct effects on dressing percent, ribeye area, marbling score, and yield grade with all values increasing with increasing length of finishing period (Table 3).

Crossbred cattle with potential for muscular hypertrophy can be used to produce a large quantity of a lean, tender product. Cattle produced from some sire breeds with this trait may be less efficient at gaining live weight. Altering the length of finishing period had a greater effect than gender for weight characteristics, such as slaughter weight, hot carcass weight, and dressing percentage, whereas gender had more effect on individual carcass components. The interaction of sire breed with length of finishing period and with gender for several carcass traits, indicates a potential advantage to tailoring postweaning management to animal genotype for the production of meat, even for cattle of similar mature weight.

Future Direction: Research on this study has been completed.

Table 3. Effect of length of finishing period on performance during the finishing phase and carcass characteristics of bulls and steers sired by Hereford, Limousin, or Piedmontese bulls and finished for 90- or 132-days

Item	Length of finishing period, days 90	132	SE
ADG, lbs/d	3.0	2.8	0.02
Feed efficiency, lbs gain/lb feed	0.16	0.15	0.002
Dressing percentage	58.5	59.6	0.10
Ribeye area, in^2	13.0	13.9	0.07
Marbling score	9.9	11.3	0.11
Yield grade	1.9	2.0	0.03

Relevant Publications:

Grings, E.E., R.E. Short, and M.D. MacNeil. 2001. Interactions in postweaning production of F1 cattle from Hereford, Limousin, or Piedmontese sires. J. Anim. Sci. 79:317-324.

MacNeil, M.D., R.E. Short, and E.E. Grings. 2001. Characterization of topcross progeny from Hereford, Limousin or Piedmontese sires. J. Anim. Sci. 79:1751-1756.

Short, R.E., M.D. MacNeil, M.D. Grosz, D.E. Gerrard, and E.E. Grings. 2002. Pleiotropic effects in Hereford, Limousin, and Piedmontese F2 crossbred calves of genes controlling muscularity including the piedmontese myostatin allele. J. Anim. Sci. 80:1-11.

Table 1. Interaction of gender, sire breed, and length of finishing period on performance and carcass characteristics of bulls and steers sired by Hereford, Limousin, or Piedmontese bulls and finished for 90– or 132-days

Item	Length of finishing period, days	Hereford Bull	Hereford Steer	Limousin Bull	Limousin Steer	Piedmontese Bull	Piedmontese Steer	SE
Slaughter wt, lbs	90	1164	1107	1155	508	1118	1096	3.2
	132	1267	1184	1291	1217	1212	1203	
Hot carcass wt, lbs	90	675	629	664	653	691	651	1.91
	132	739	689	772	719	748	724	
Shear force, lbs	90	7.7	9.1	7.6	8.0	8.2	7.0	0.11
	132	7.5	6.7	7.7	7.7	7.5	7.3	
Fat depth, in	90	0.21	0.37	0.21	0.31	0.11	0.17	0.005
	132	0.24	0.52	0.24	0.33	0.13	0.23	
Primal cuts[a], lbs	90	179	161	178	167	193	172	0.59
	132	197	172	209	185	210	189	

[a]Primal cuts = weight of chuck, rib, shortloin, sirloin, and round for one-half of the carcass.

Table 2. Performance and carcass characteristics affected by an interaction of gender (bull versus steers) and sire breed (Hereford-, Limousin-, or Piedmontese-sired) during the finishing period

Item	Hereford Bull	Hereford Steer	Limousin Bull	Limousin Steer	Piedmontese Bull	Piedmontese Steer	SE
ADG, lbs/d	3.2	2.6	3.3	2.8	2.9	2.6	0.02
Feed efficiency, lbs gain/lbs feed intake	0.17	0.13	0.18	0.15	0.15	0.14	0.002
Ribeye area, in^2	86.7	74.0	88.6	82.2	92.4	97.1	0.45
Dressing percentage	58.1	57.7	58.6	58.7	61.0	59.8	0.10
Marbling score[a]	9.8	13.5	9.9	11.4	7.7	11.4	0.11
Kidney, pelvic and heart fat, lb	1.9	2.5	2.1	2.6	1.5	2.6	0.03
Yield grade	1.8	3.0	1.8	2.4	1.0	1.5	0.03

[a]Marbling score, 1 = devoid to 28 = abundant.

Feeding and Marketing Cull Cows

R.N. Funston, J.A. Paterson, K.E. Williams, and A.J. Roberts

Problem: Sale of cull cows accounts for 15-25% of yearly gross revenues of cow-calf operations in the United States. Properly managing and marketing cull cows may mean the difference between a profit and a loss for a year. Feeding cull cows for a period of time before selling may improve quality of animals and overall profitability. Beef from market cows is widely used in the retail and food service sector in a variety of product forms, not all of which is ground. Yet many beef producers view market cows as culls rather than an important source of beef for the food industry and therefore may overlook opportunities to add value to market cows, and thereby increase returns from this portion of their operation. Thus, it is important to identify management practices and cow characteristics that influence factors affecting value of market animals. Objectives of this research were to determine effects of steroid implants, initial body weight (**BW**) and body condition score (**BCS**) on feedlot performance, slaughter weight and carcass characteristics of cull cows fed a high concentrate diet for approximately 90 days.

Procedures: Cows from three different sources were fed approximately 90 days from mid-July through mid-October in Miles City, MT, or early August through early November in Billings, MT. Forty-nine cull cows (BCS = 6; BW = 1153 lbs) from Fort Keogh Livestock and Range Research Laboratory and 37 purchased cows (BCS = 4.7; BW = 1166 lbs) were fed at a commercial feedlot near Miles City. Fifty cows fed at Billings were from one ranch and had an initial weight of 1218 lbs and BCS = 5.3. At beginning of the study, cows were weighed (initial BW), visually appraised for BCS, and treated with pour-on for external and internal parasites. One-half of cows at each location were allotted to implant treatment (Synovex-Plus®, Fort Dodge Animal Health, Overland Park, KS) by initial weight and BCS. Cows were fed a warm-up diet (50-60% concentrate, DM basis) for 14 days, and then fed a finishing (80-85% concentrate, DM basis) feedlot ration consisting of corn silage, chopped hay, whole corn, cracked wheat, and supplement for the remainder of the study.

A second feeding project was conducted with local ranchers to determine feasibility of feeding cull cows from a traditionally low cow market (November) through March, a period of generally increasing prices. A total of 80 cull cows from four ranches were placed in a commercial feedlot near Miles City in mid-November. Cows were weighed and processed as in the previous study, except that all cows were implanted with Synovex-Plus®. Cows were started on a warm-up diet (50-60% concentrate, DM basis) for 14 days and then fed a finishing (80-85% concentrate, DM basis) feedlot ration for the remainder of the period. Initial weight of cows was 1038 lb and average BCS was 4.37. Cows ranged in age from 2 to 10 years old (not all ages were known). A cattle buyer valued all animals on an individual basis at beginning of the feeding period, average in-value was $0.38/lb on a live weight basis. Cattle were fed an average of 110 days and marketed in three different groups. Cows had a final weight of 1558 lb and averaged 4.47 lb/day average daily gain. Older cows were sent in two groups to a cow processing plant in Minnesota. Younger cows (2 to 3 years old) were sold on a fed cattle grid to a cattle-processing plant in Colorado.

Findings: Initial weight at beginning of feeding was positively associated with hot carcass weight, back fat, ribeye area, marbling score, and yield grade. Likewise, an increase in initial BCS resulted in heavier final and hot carcass weights and increased backfat, ribeye area, and marbling score. Neither initial weight nor body condition influenced average daily gain. Implanted cattle had 65 lb heaver final weight, 0.48 lb greater ADG, 56 lb heavier carcass weight, 1.4 inch larger ribeye, and 25 units less marbling.

In the second study, initial BCS was negatively correlated with initial value and days on feed, which was probably a function of younger animals weighing less on arrival and fed longer. Initial value was positively correlated with days on feed and negatively correlated with final weight; again, this was probably a function of age with younger animals valued higher, fed longer, and finishing at a lighter weight. Days on feed and final weight were negatively correlated, which also is probably a function of younger animals being lighter even though they were fed longer. Overall, cattle in this project returned approximately $30/head over what they were estimated to be worth if sold at the beginning of the feeding period.

Neither initial weight nor body condition affected feedlot performance of cull cows in this research project. Implanting, however, had a dramatic effect on improving feedlot performance and increasing hot carcass weight and ribeye area. While it is important to consider seasonality of cull cow prices and price differences between cull cow slaughter grades when deciding whether to feed cull cows, there is potential for increasing revenues from cull cow sales by implementing this management strategy.

Future Direction: Results of this study are considered definitive.

Relevant Publications:

Funston, R.N., J.A. Paterson, K.E. Williams, and A.J. Roberts. 2002. Feeding and marketing cull cows. 51st Montana Nutrition Conference, Montana State University, Bozeman.

Vaccines Against Reproductive Hormones to Sterilize Stocker Beef Heifers

T.W. Geary and E.E. Grings

Problem: Approximately 10% of beef heifers are pregnant upon entering feedlots annually. This represents a significant problem to the beef industry because pregnant heifers have decreased feedlot performance, increased mortality, lower carcass quality and dressing percentage, and as a result are worth less to the beef industry. The increased mortality and poorer overall performance among heifers comprise the primary reasons why producers are paid less for heifer than steer calves. Surgically spaying heifers increases costs, morbidity, and mortality and is generally not feasible. Many feedlots examine heifers for pregnancy and abort pregnant heifers upon entering the feedlot, but this practice also increases costs, morbidity, and mortality, and the effectiveness of most abortive compounds is less than 100%. Feedlot heifers today are generally fed melengestrol acetate (**MGA**; a synthetic progestin) to prevent estrous activity while in the feedlot, but feeding MGA is not practical for stocker programs.

Progestin implants have been evaluated for their ability to suppress estrus and prevent pregnancy among heifers on pasture. Others have used immunization against gonadotropin releasing hormone (**GnRH**), a reproductive hormone, to sterilize heifers destined for the feedlot. However, the antigens used by these researchers to sterilize heifers were synthesized by adhering GnRH to antigenic proteins, and these compounds will not be approved by the Food and Drug Administration because of problems associated with consistency between batches of antigen. The goal of this study was to evaluate the ability of genetically engineered antigens containing the GnRH amino acid sequence within the amino acid sequences of two antigenic proteins (ovalbumin and thioredoxin). This study was a collaborative effort with Dr. Jerry Reeves at Washington State University where antigens were synthesized.

Procedures: Forty-eight beef heifers were sorted into four treatment groups by age and weight approximately 2 months after weaning. Each heifer received a primary immunization at week 0 and booster immunizations at week 6 and 12 containing 1 mg of protein (antigen) in 1 mL of adjuvant administered in the mammary gland. Heifers were immunized against either a fusion protein consisting of thioredoxin with seven GnRH peptides (**tGnRH**), a fusion protein consisting of ovalbumin with seven GnRH peptides (**oGnRH**), a cocktail of tGnRH/oGnRH, or a cocktail containing thioredoxin and ovalbumin (control). Six heifers within each treatment received Synovex H® implants at week –2. Weekly blood samples were collected from week –2 to 26 to determine serum progesterone concentrations and GnRH, thioredoxin, and ovalbumin antibody titers. Weekly serum progesterone concentrations were used to assess estrous cycling status among heifers within treatment groups. Antibody production (titers) against each component was used to confirm immune responses against only those antigens for which heifers were vaccinated. One control heifer died before completion of the study and was removed from analyses.

Findings: Anti-GnRH antibody titers (Figure 1A) increased after the first booster injection, peaked after the second, and remained elevated through the end of the study for GnRH immunized heifers. Heifers that were immunized against oGnRH had greater GnRH antibody titers than tGnRH heifers, but did not differ from tGnRH/oGnRH heifers. Estrous cycles were suppressed in 10/12, 12/12, 11/12 and 0/11 tGnRH, oGnRH, tGnRH/oGnRH, and control heifers, respectively (Figure 1B). At slaughter, uterovarian weights were lighter for GnRH immunized heifers than controls. Synovex H implanted heifers had greater average daily gain from week 6 to 26 and week –2 to 26, greater ribeye area, and lower kidney, pelvic, and heart fat, yield grade, and quality grade than non-implanted heifers.

We conclude that immunization against the tGnRH, oGnRH, and tGnRH/oGnRH fusion proteins produced anti-GnRH antibodies that suppressed estrous cycles in 83, 100, and 92% of heifers, respectively, without affecting feedlot or carcass performance. Implanting heifers with

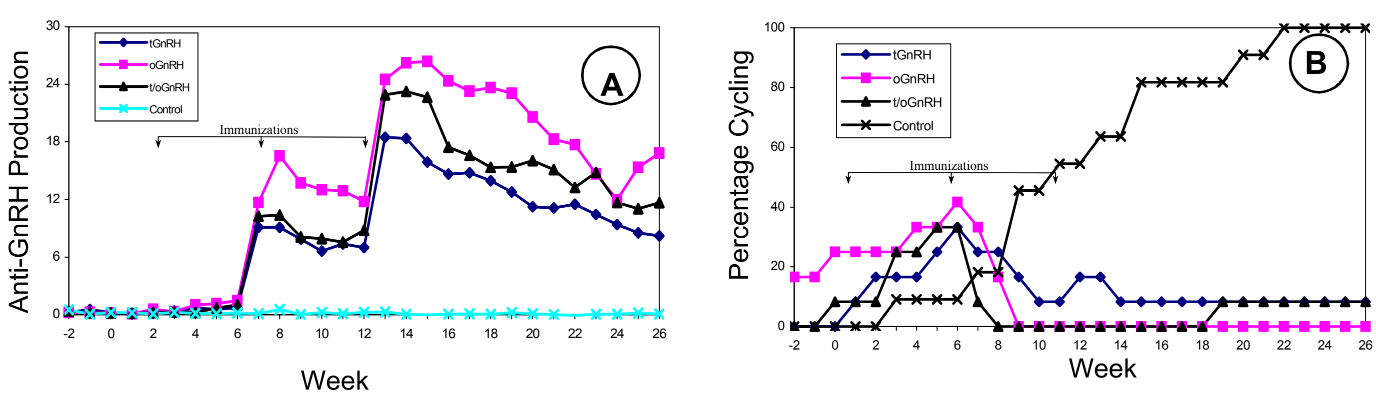


Figure 1. Mean anti-GnRH antibody production (A) and percentage of heifers cycling (B) that were immunized against tGnRH, oGnRH, tGnRH/oGnRH, or thioredoxin/ovalbumin (control) antigens.

Synovex H® improved average daily gain, ribeye area, and yield grade. Protocols that yield greater than 95% estrous suppression may someday replace surgical spaying of heifers.

Future Direction: We are interested in continuing research in this area and will do so as heifers become available. Future studies will focus on antigen formulation, route of administration, and methods to improve antigenicity to decrease the injection number and frequency.

Relevant Publications:

Geary, T.W., J.J. Reeves, D.W. Schafer, R.R. Evans, R.D. Randel, L.M. Rutter, R.G. Sasser, R. Guardia, B. Alexander, D. Holcombe, D.R. Hanks, and D.B. Faulkner. 1997. Norgestomet implants prevent pregnancy in beef heifers on pasture. J. Anim. Sci. 75:3089-3093.

G. Forage Quality

Ruminant animals hold a unique place in the agricultural sector because of their ability to utilize feedstuffs that are not digestible by simple-stomached animals (including humans). This allows them to graze forages and utilize by-products of other crops. Understanding and manipulating the efficiency of feedstuff utilization requires knowledge of both the rumen microbial ecosystem and the nutrition of the animal itself. Evaluating the quality of food eaten by a grazing animal is complicated by the diet selections process occurring across the extensive landscape. Simple techniques are needed to evaluate forage quality relative to the efficiency of ruminal fermentation and its relation to animal performance. Research focusing on studying nutrients needed by livestock in small quantities allows for a further improvement in efficiency of growth and production.

Effect of Hay Source and Level on Tissue Trace Mineral Concentrations and Apparent Absorption in Growing Steers

E.E. Grings and W.W. Poland

Problem: Understanding the utilization of minerals from forages is critical to developing cost effective supplementation strategies; however, information on mineral utilization from forages is lacking. Western wheatgrass is a major forage species on Northern Great Plains rangelands. Mineral profiles of western wheatgrass have been reported, but there is little information on the availability of these minerals to cattle. While studies have been conducted on the relative availability of macrominerals from legumes compared with grasses, there is limited information on trace minerals. This study was designed to evaluate the impact of increasing intake on tissue mineral concentrations of steers fed western wheatgrass or alfalfa hays along with measures of apparent absorption.

Procedures: *Tissue Mineral Concentrations:* Yearling crossbred steers that had been grazing rangeland throughout the summer were used in this study. Forty steers (average initial body weight = 834 lbs) were fed alfalfa hay for 3 weeks before the beginning of the feeding period. Steers were allotted to one of four treatments consisting of one of two forages (alfalfa or western wheatgrass hay) fed at two levels of intake (0.019 and 0.024 lbs/lb body weight). Steers were fed through electronic feed doors and daily intake monitored. Steers were weighed weekly to maintain respective intakes as a percentage of body weight. Twenty-four steers (final weight average = 902 lbs) were used for the collection of tissue data and 16 steers were used in the mineral balance study.

Due to the capacity of the slaughter plant, 24 steers were slaughtered in two groups after either 90 or 97 days on feed. Internal organs (liver, heart, and kidney) were collected and weighed. Organ weights, mineral concentrations, and total organ minerals were expressed on a dry matter (**DM**) basis.

Mineral Balance Study: Sixteen steers were assigned to four treatments in a factorial manner with two hay sources and two intake levels. After 90 days of receiving their respective diets, steers were placed in metabolism crates. Steers did not consume feed at their respective intake levels while in the metabolism crates; therefore, intake level was dropped from the analysis and only the effect of hay source was evaluated. Feed samples were collected daily and composited across the entire collection period. Water intake was monitored, a sample collected and any contribution of mineral via water was accounted for in the daily mineral intake. During the final 5 days of the study, fecal and urine samples were collected daily.

Findings: Alfalfa hay contained greater concentrations of all nutrients than grass hay except zinc (Table 1). Alfalfa hay mineral concentrations were well above recommended levels for growing cattle for calcium, phosphorus, magnesium, potassium, sodium, iron, and manganese. Although grass hay contained less of these nutrients, levels were still above those suggested for growing cattle for calcium, magnesium, potassium, iron, and manganese but were below those for phosphorus and sodium. Dietary levels of 10 ppm copper and 30 ppm zinc are suggested for growing cattle and neither hay met this minimum level.

The greater concentrations of nutrients in the alfalfa hay was reflected in the effect of hay source on trace mineral intakes. Mineral intakes were greater for alfalfa-fed steers for all minerals except zinc, which was greater for grass-fed steers.

Table 1. Nutrient composition of alfalfa and western wheatgrass (grass) hay fed to steers at two levels of intake

	Alfalfa	Grass
	——%, DM basis ——	
Crude protein	16.7	8.8
ADF	43.2	40.9
NDF	51.6	63.1
Calcium	1.21	0.46
Phosphorus	0.23	0.13
Magnesium	0.29	0.16
Potassium	2.51	1.57
Sodium	0.12	0.06
	——ppm, DM basis ——	
Iron	426	143
Zinc	16	19
Copper	9	3
Manganese	30	27
Molybdenum	3.6	1.3

Tissue Mineral Concentrations: Liver weights were heavier for alfalfa- than grass-fed steers. Liver weights are often increased in animals fed increased levels of nutrition. Steers fed the two hay sources did not differ in weight of other organs.

Heart copper concentrations tended to be greater in steers on the high than low intake level. No other mineral concentrations or total organ levels were affected by intake level.

Manganese concentrations in the kidney and heart were 0.4 and 0.34 ppm greater for alfalfa-fed steers than grass-fed steers. Increased manganese concentrations resulted in increased total tissue levels of manganese in the heart but not kidney (total muscle mass was not measured). Heart is considered to be the organ most sensitive to manganese intakes. Increased liver weight for alfalfa-fed steers resulted in an increase in total liver manganese for these animals.

Concentrations of liver copper were 13.2 ppm less in grass-fed steers compared with alfalfa-fed steers. Liver copper concentration is considered to be a sensitive indicator of intake for copper and this was true in this study where grass hay contained only 3 ppm copper compared with 9 ppm in alfalfa hay. Liver concentrations of less than 20 ppm dry weight are considered to indicate a deficiency situation. Steers consuming hay of only 3 ppm had liver concentrations slightly greater than this suggested minimum. The decreased liver mass in these steers compared with alfalfa-fed steers may have played a role in concentrating the liver copper. It appears that dietary factors affecting liver weight should be considered in interpreting liver copper concentrations as a diagnostic tool.

Total heart zinc was 2.8 mg greater for grass- than alfalfa-fed steers. Kidney zinc concentrations tended to be affected by the hay source by level interaction. This was due to an effect of intake level on kidney zinc concentrations for grass hay while there was no effect of intake level for steers fed alfalfa hay. Kidney zinc concentrations were greater for steers fed the lower level of grass hay (82.9 ppm) than those fed the high level (72.7 ppm). Although zinc intake was similar between steers fed alfalfa at the high intake level and those fed grass at the low intake level, kidney zinc concentrations were greater in steers fed grass hay at the low intake. This may indicate a greater bioavailability of zinc from grass compared to alfalfa hay.

Mineral Balance Study: Intake of copper and zinc (Table 2) differed between alfalfa- and grass-fed steers while in metabolism crates, whereas intakes of manganese did not. Differences in mineral balance were due primarily to differences in either intake or percent apparent absorption. Losses of mineral in the urine had little effect on mineral balance.

Table 2. Least square means of intake (oz/d) and percent apparent absorption and retention ± S.E. of copper, zinc, and manganese of steers fed two different hays

	Copper	Zinc	Manganese
Intake, oz/d			
Alfalfa	2.7 ± 0.09	5.1 ± 0.27	9.3 ± 0.42
Grass	0.9 ± 0.10	6.0 ± 0.29	8.2 ± 0.45
Absorption, % of intake			
Alfalfa	23.7 ± 12.5	-7.7 ± 6.1	29.0 ± 3.6
Grass	12.7 ± 13.4	65.6 ± 6.5	44.6 ± 3.6
Retention, % of intake			
Alfalfa	21.9 ± 12.5	-8.6 ± 6.1	27.4 ± 3.8
Grass	8.8 ± 13.4	64.4 ± 6.5	43.9 ± 3.8

The difference in apparent absorption of manganese between alfalfa and grass was related to the difference in the percentage of intake absorbed, but not total amount of mineral absorbed. The opposite was true for and copper, for which the percentage of mineral absorbed did not differ between hays, but the total amount absorbed differed due to differences in mineral concentrations of the hays.

Zinc absorption and retention were negative for steers fed alfalfa hay, whereas steers fed grass hay absorbed over 65% of the feed zinc. The higher calcium concentration in the alfalfa hay or a greater number of cation binding sites may have negatively impacted zinc absorption. Other researchers have reported negative zinc absorption in ruminants fed alfalfa forages.

Copper retention from grass hay was very low, only about 9% of dietary intake. Steers receiving grass hay were therefore limited in copper from both low dietary levels as well as low absorption. Various factors can limit copper absorption through binding or competition for absorption sites in the gastrointestinal tract. The improved zinc absorption for grass hay compared with alfalfa could indicate an increased competition between the two elements for absorption. Molybdenum, sulfur, and iron have all been shown to interfere with copper absorption. Molybdenum was not high in the grass hay (1.3 ppm) and the hay had a copper:molybdenum ratio of 2.3. Ratios of less than 2.0 have suggested to be limiting to copper absorption.

Manganese absorption and retention differed between hays as a percentage of intake even though actual intakes did not differ. These apparent absorption values of 29 and 45% are higher than previously reported values for forages.

Differences in apparent absorption between hays were reflected in total liver copper, kidney copper, and heart zinc (both concentration and total). Total liver zinc was greater for steers fed alfalfa than those fed grass hay even though absorption and retention of zinc from alfalfa was negative.

Organ trace mineral levels and concentrations can be altered by feeding different forages. Some of these alterations may be due simply to differing trace mineral concentrations in the forages while others may be related to differing solubilities within the gastrointestinal tract. Additional work is needed to evaluate the interrelationship of altering organ mass through changing nutrient densities on mineral metabolism. While response to increasing mineral intake of inorganic sources is used as a measure of mineral bioavailability, utilizing increased intake is generally not sensitive enough for evaluation of forage mineral bioavailability.

Future Direction: No future studies are currently planned in this area of research.

Relevant Publications:

Grings, E.E. and W.W. Poland. 2000. Effect of hay source and level on tissue trace mineral concentrations in growing steers. Proc. West. Sec. Amer. Soc. Anim. Sci. 51:490-493.

Grings, E.E. and W.W. Poland. 2000. Effect of hay source and level on tissue trace mineral concentrations in growing steers. Proc. Beef Talk Live 2000. p. 6-11. Dickinson, ND. November 2000.

Poland, W.W., E.E. Grings, J. Karn, and L. Manske. 2000. Mineral concentrations and availability of forages for grazing livestock in the Northern Great Plains. Proc. Beef Talk Live 2000. p. 1-2. Dickinson, ND. November 2000.

Poland, W.W., E.E. Grings, J. Karn, and L. Manske. 2000. Mineral concentrations and availability of forages for grazing livestock in the Northern Great Plains—Interim Progress Report. Proc. Beef Talk Live 2000. p. 3-5. Dickinson, ND. November 2000.

Selenium Concentration and Distribution in Range Forages from Four Locations in the Northern Great Plains

T.L. Lawler, J.B. Taylor, E.E. Grings,
J.W. Finley, and J. Caton

Problem: Previous research has shown anticarcinogenic properties associated with supranutritonal levels of selenium supplementation for humans. It has been suggested that the antioxidative properties of selenium might be one mechanism for cancer reductions. Beef, on the average, is the single greatest contributor to human dietary selenium in North America. Geographical region and soil selenium concentrations have been reported to be useful in predicting selenium concentrations of beef. The objectives of this study were to assess selenium concentration in diet versus available forage and to evaluate the distribution of selenium in forage fractions across the grazing season.

Procedures: Four locations representing high to low selenium areas throughout the Northen Great Plains were selected. Locations included a ranch near Pierre, South Dakota (**PSD**), a ranch near Fargo, North Dakota (**FND)**, a Research and Extension Center near Jamestown, North Dakota (**JND**), and USDA-ARS, Miles City, Montana (**MMT**). In 2001 and 2002 samples were collected in late May, mid-July and late August 2001 and 2002. Laboratory analysis has been conducted on the May and July 2001 samples. Four sites at each location were selected for sampling. Within each site, forage from 10 clipped areas was pooled. After clipping, diet samples (masticate) were collected using ruminally cannulated cattle tethered at the site. Total clipped grass, grass leaf, grass stem, and masticate were analyzed for selenium content.

Findings: Selenium concentrations were not different between masticate and total grass samples within each location. Selenium concentrations were also not different between grass stem and grass leaf. Seasonal changes in forage selenium were inconsistent across seasons at the different locations. Additional forage samples have been collected and should provide further insight into seasonal changes in forage selenium concentrations.

Table 1. Selenium concentrations (ppm) in range forage in two different seasons (organic matter basis)

	Period			
Location	June	July	SE	P-value
PSD	4.68	3.65	0.60	0.28
FND	0.88	0.00	0.37	0.14
JND	0.37	0.86	0.16	0.04
MMT	0.27	0.55	0.02	0.01

Future Directions: Additional samples were collected in August 2001 and May, July, and August 2002 and are being analyzed for selenium concentration. Additional sites near Pierre, SD and at Miles City, MT were added to further evaluate seasonal variation in selenium concentration. Forage samples collected at these sites in 2002 have been sorted by species and by live and dead tissue. This sampling will be repeated in 2003. This additional sampling will provide information on the potential for seasonal variation among different forage species.

Relevant Publications:

Lawler, T.L., J.B. Taylor, E.E. Grings, J.W. Finley, and J.S. Caton. 2002. Selenium concentration and distribution in range forages from four locations in the Northern Great Plains. Proc. West. Sec. Amer. Soc. Anim. Sci. 53:7-9.

Relationship Between Esophageal Diet Samples, Clipped Forage Samples, and Weight Gain of Steers

M. Blümmel and E.E. Grings

Problem: Declining forage quality and the resultant decrease in the growth rate of young cattle during the late summer grazing season in the Northern Great Plains are well documented. Attempts to counterbalance these effects by supplementation were met with only varying success. Efficient supplementation requires a thorough knowledge of the ruminal fermentation characteristics of the basal forages. Emphasis is thereby placed on the estimation of fermentation rates of forages and forage fractions to ultimately better match rumen fermentative processes. *In vitro* production tests are frequently recommended for the measurements of these rates mainly because of their analytical convenience. The objective of the present work was to describe gas production kinetics of cattle diets (esophageal extrusa) and clipped forage from different growing seasons and to relate these kinetics to weight gain of steers.

Procedures: The monthly weight gains of steers (initial live weight average = 638 lbs) were determined from May to September in 1993 and 1994. Each month extrusa samples was collected from esophageal cannulated yearling heifers. Crude protein (**CP**) and in vitro organic matter digestibility (**IVOMD**) analysis was done following standard procedures and 48-hour IVOMD was determined in nitrogen (**N**) unsupplemented incubation medium. *In vitro* gas production was determined using 100-ml calibrated glass syringes. Esophageal diet samples were incubated in N unsupplemented (**N-low**) incubation medium while clipped forage samples were also incubated in medium containing N (**N-rich**) as ammonium bicarbonate. *In vitro* gas volumes were recorded over 96 hours of incubation. Kinetics of gas production was described by the exponential models $y = B^*(1\text{-}exp^{-c^*t})$ and $y = B^*(1\text{-}exp^{-c^*(t\text{-}lag)})$ and the Boltzmann sigmoidal model y = Top/(1+exp ((V50-t)/Slope)).

Findings: Esophageal diet samples had significantly higher CP contents and IVOMD than clipped forage suggesting the selective grazing of higher quality forages or forage parts (Table 1). Over all periods and both years, CP and IVOMD of extrusa accounted for 84 and 75% of the variation in weight gain, respectively. In contrast, CP and IVOMD of clipped forage accounted for only 50% of the variation in weight gain. These findings support the greater significance commonly attributed to extrusa than clipped forage in predicting animal performance. In both years, weight gain tended to be higher in August - September than in July - August despite slightly lower CP and IVOMD contents. Rains in the August - September period increased forage production, which together with a decrease in ambient temperature, might have facilitated higher feed intake resulting in higher weight gain.

The relationship between accumulating *in vitro* gas volume measurements from 2 to 96 hours as obtained from the incubation of extrusa, clipped forage, and clipped forage plus N and weight gain of steers is presented in Figure 1.

Table 1. Gains (WG; lbs/d) of steers, crude protein (CP; %), and *in vitro* organic matter digestibility (IVOMD; %) of esophageal diet samples (EDS) and clipped forage samples (CFS)

		CP		IVOMD	
Period	Weight gain	EDS	CFS	EDS	CFS
May - Jun 93	3.30	14.1	9.4	68.4	54.6
Jun - Jul 93	2.02	10.8	9.2	63.9	52.5
Jul - Aug 93	1.85	9.5	8.4	60.6	51
Aug - Sep 93	1.87	8.5	7.8	58.9	49.5
May - Jun 94	3.12	14.7	8.7	67	53.6
Jun - Jul 94	2.00	10.6	7.9	60.4	52
Jul - Aug 94	1.03	8.1	6.9	54.7	49.5
Aug - Sep 94	1.85	7.7	6.5	53.5	46.2
Mean	2.13	10.5	8.1	60.9	51.1

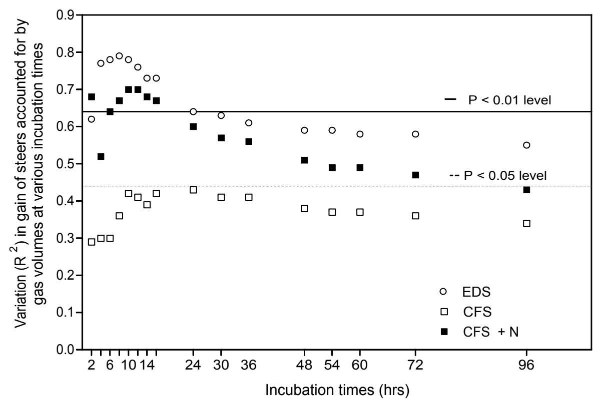


Figure 1. Relationships between in vitro gas volumes of esophageal diet samples (EDS) and clipped forage samples (CFS) measured after various hours of incubation and weight gain of steers.

Approximately 79% of the variation in weight gain was accounted for by gas production from extrusa measured at early hours of incubation, while no significant relation was observed for gas production from clipped forage incubated in N-low medium. This relationship was considerably improved by adding N to the incubation of clipped forage, and up to 70% of the variation in weight gain was thus accounted. Nitrogen recycled via the salivary glands can be recovered in extrusa, and this N will supplement ingested forage N. *In vitro* fermentation of clipped forage in N-low incubation medium neglects the possible contribution of recycled N, resulting in an under-prediction of forage utilization in the animal. Although incubation of clipped forage in N-rich medium improved the relationship with weight gain, less of the variation in weight gain was accounted for (70%) than by fermentation of extrusa. The reason for this could be selective foraging behavior resulting in intake of forages of a higher quality than suggested by clipped forage analysis.

None of the employed kinetic models fit the gas production profiles of samples from all periods. Except for the late periods, the exponential model with lag phase provided a better fit for extrusa and clipped forage in N-rich medium than the simple exponential or sigmoidal models. However, the sigmoidal model described the fermentation of clipped forage incubated in N-low medium better than either one of the exponential models. This problem of describing the gas production profiles of extrusa, clipped forage, and clipped forage plus N uniformly by one model is illustrated based on extrusa and clipped forage samples collected in Period I in 1993 (Figure 2).

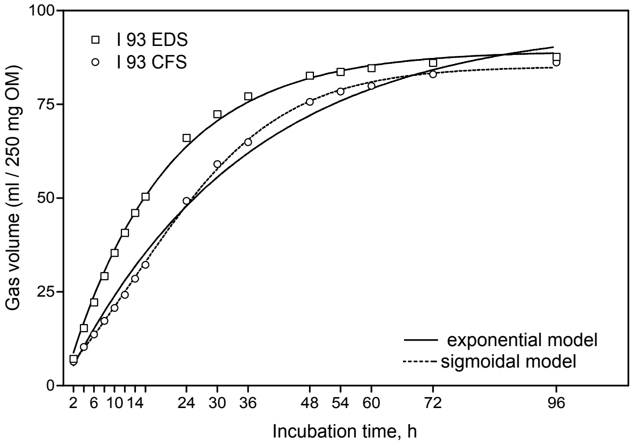


Figure 2. Comparison of gas production profiles of an esophageal diet sample and a clipped forage sample from the same period (for model parameters see Table 1).

Based on extrusa incubations, about 87% of the variation in weight gain was accounted for by a multiple regression combining IVOMD with gas production measured after 30 hours. IVOMD accounted for 75% of the partial variation in weight gain, and gas production measured after 30 hours accounted for 12% of the partial variation in weight gain. The regression coefficient was positive for IVOMD but negative for gas production.

Future Direction: Additional work is being conducted on use of extrusa samples in the gas production system for prediction of diet quality.

Relevant Publications:

Blümmel, M. and E.E. Grings. 2000. Relationship between esophageal diet samples, clipped forage samples, and weight gain of steers. Proc. West. Sec. Amer. Soc. Anim. Sci. 51:267-271.

Blümmel, M.R., E.E. Grings, and M.R. Haferkamp. 2000. Predicting weight gain of grazing steers by the kinetics of *in vitro* gas production of extrusa samples fermented in nitrogen supplemented and unsupplemented incubation medium. European Assoc. of Anim. Production Symposium. P. 19-20. (Abstract)

Comparison of Elk Fecal and Rumen Microbial Suspension to Predict Feed Degradation and Adaptation

M. Blümmel, R.E. Short, and E.E. Grings

Problem: In the ruminant, most microbial substrate degradation occurs in the rumen but can also occur in the hindgut. Microbial activity is maintained in fresh fecal matter, potentially allowing for the replacement of rumen by fecal microbial suspension for *in vitro* studies. This can help in research when routine rumen fistulation is problematic, as in un- or semi-domesticated ruminants. These animals may share grazing habitats with domesticated ruminants yet exhibit different adaptative mechanisms. In Western North America, for example, cattle abort after the consumption of pine (*Pinus ponderosa*) needles while elk (*Cervus elaphus*) do not. This could be related to ruminal microbial adaptation in elk but the study of this phenomenon in the laboratory requires representative microbial inoculum. This work compares *in vitro* fermentation characteristics of forages in rumen and fecal microbial suspensions from elk and also studies the possible adaptation in elk rumen and hindgut microbial populations to pine needles.

Procedures: Ruminally cannulated female elk had free-choice access to round-baled alfalfa hay throughout these studies. For the second experiment, the elk's microbial flora was gradually exposed to pine needles introduced though the rumen cannulas every second day for 2 weeks. After adaptation to pine needles, the animals were again given free-choice access to alfalfa hay for 4 weeks until slaughter. Cecum and colon of slaughtered animals were removed immediately, put into pre-warmed thermos containers and taken to the laboratory. Cecum and colon inoculum was treated as that collected from the rumen. All incubations were conducted in 100 ml calibrated glass syringes. Alfalfa hay, barley straw, and corn silage were used as substrates for the incubations in the first experiment and pine needles were used in the second experiment.

Findings: In general, ranking of substrates by gas production agreed between inoculum sources for the second half of the 96-hour incubation, but differed for the first half depending on the substrate (Figure 1). Using a best-fit model, asymptotic gas volumes in ruminal and fecal microbial suspensions were well related. Across ruminal, fecal, and cecal content microbial suspensions, there was a reasonable relationship between gas production measured and gas production predicted from the volatile fatty acid analysis in the incubation after 24 hours. However, the agreement was greater within ruminal and cecal contents than within fecal microbial suspensions.

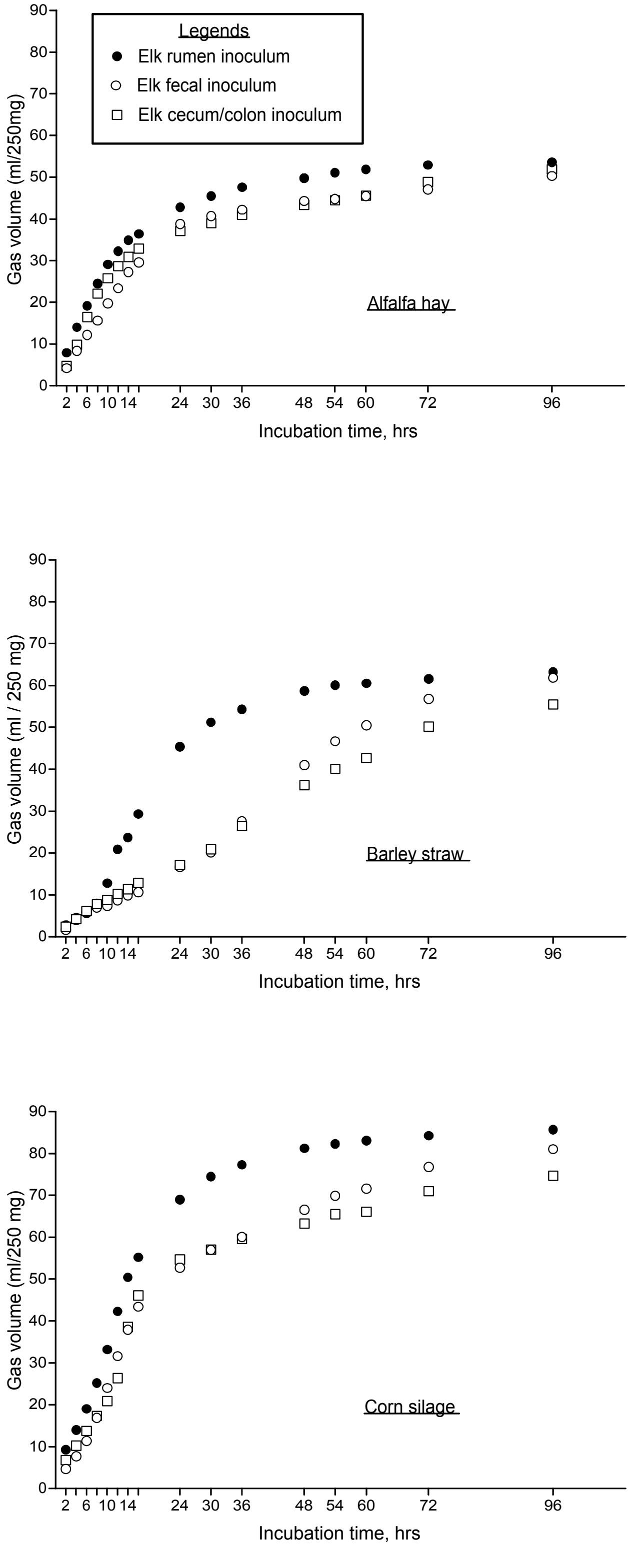


Figure 1. Gas production profiles of forages in different microbial inoculums.

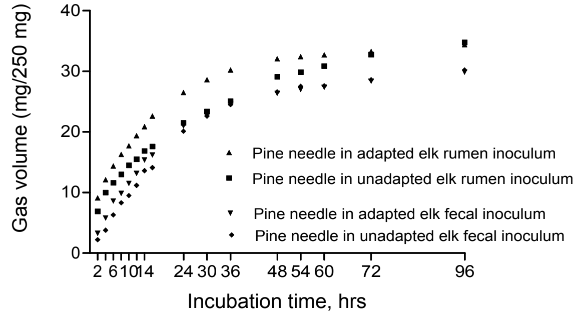


Figure 2. Gas production profiles of pine needles incubated in rumen and fecal inoculum from adapted and un-adapted elk.

Rumen and fecal microbial suspension could rank forages differently at some incubation times. Time series measurements of gas production and fittings of appropriate curves can potentially overcome this problem because asymptotic gas production and kinetic variables were reasonably correlated, even though fermentation was substantially slower in hindgut inoculum. However, short chain fatty acid profiles in rumen and hindgut incubations differed substantially and more work is required to understand the responsible mechanisms.

In the case of rumen microbial suspension, adaptation of elk to pine needles has a pronounced positive effect on rate of gas production without greatly affecting asymptotic values (Figure 2). This was reversed when pine needles were incubated in fecal microbial suspension for adapted elk. Therefore, caution should be exercised in extrapolating findings on adaptation using hindgut inoculum to draw conclusions on ruminal microbial adaptation.

Future direction: No additional studies are planned.

Relevant publications:

M. Blümmel, R.E. Short, and E.E. Grings. 2002. Comparison of elk (*Cervus elaphus*) fecal and rumen microbial suspension to predict feed degradation and adaptation. Proc. West. Sec. Amer. Soc. Anim. Sci. 53:540-543.

A Mechanistic Approach to the Estimation of Intake of Ruminants by Methane Excretion and *In Vitro* Fermentation Characteristics

M. Blümmel, E.E. Grings, A.R. Moss, and D.I. Givens

Problem: Reliable estimation of feed intake of grazing animals is necessary for many management decisions, but can be difficult to obtain. Ruminal methane (**CH_4**) excretion could conceptually serve as a means to validate various estimates of intake if additional information about rumen stoichiometrical relationships can be provided. Information on short chain fatty acids (**SCFA)** proportions and on the efficiency of microbial production is required for these calculations. The objective of this work was 1) to examine how well intake of roughages can be predicted from measurements of CH_4 excretion *in vivo* and from SCFA and microbial efficiency measurements *in vitro* and 2) to test if precise SCFA and microbial efficiency measurements are required or if they can be replaced by applying assumed constant relationships, without unacceptable loss of accuracy.

Procedures*:* *In Vivo* and *In Vitro* Analysis: The work uses data from the *in vivo* experimentation of Moss et al. (1994) who examined the effect of sodium hydroxide (**NaOH**) and ammonia (**NH_4**) treatment of wheat, barley and oats straws (total 15) on production of CH_4 in sheep. Methane production was measured in open circuit respiration chambers and dry matter and digestible dry matter intakes were measured in metabolic cages. The 15 roughages were examined *in vitro* for true digestibility (**IVOMD**) and SCFA production. Microbial biomass production was estimated by four methods: two microbial nitrogen balances, by purine analysis, and by combined gas volume and substrate degradability measurement. Microbial efficiency was estimated by relating these measurements to 100 mg substrate truly degraded *in vitro*. *In vitro* fermentation characteristics were analyzed at roughage specific incubation times to examine fermentation characteristics at comparable microbial growth stages. These specific incubation times were obtained based on *in vitro* gas production kinetics and were based upon the time when half of the asymptotic gas volume was produced. In previous work with hays, these halftimes ($t_{1/2}$) of gas production coincided approximately with peak microbial biomass production.

Stoichiometrical Calculations: Relationships were based on calculating 1) CH_4 production from acetate (**a**): propionate (**p**): butyrate (**b**) proportions; 2) carbon (**C**), hydrogen (**H**) and oxygen (**O**) requirement for the production of 1 mol of SCFA and fermentative CO_2, CH_4, and H_2O; 3) *in vitro* true digestibility measurement; and 4) microbial biomass production per unit feed truly degraded (**EMP**). For details of the calculations see: Blümmel et al. (1997). As an example, assume 1 kg (2.2 lbs) of feed to be truly digested with a EMP of 0.3 and a SCFA ratio of 0.70 a, 0.20 p, 0.10 b: 300 g of feed will be converted into microbial biomass leaving 700 g for the SCFA complex resulting in 6.48 mol of SCFA and 2.27 mol of CH_4. It can then be calculated that 1 kg of digested feed finally results in the production of 50.8 liter (2.27mol * 22.4 l/mol) of CH_4. Therefore, in this example, 1 liter of CH_4 is associated with 19.7 g of digestible feed intake. This value can be corrected for the respective *in vitro* dry or organic matter digestibility to estimate the quantitative relationship between CH_4 produced and dry matter or organic matter consumed. In the present work analytically determined SCFA proportions and EMPs were used for these calculations as well as assumed SCFA proportions of 0.70a: 0.20p: 0.10b; 0.60a: 0.30p: 0.10b and 0.50a: 0.40p: 0.10b and assumed EMPs of 0.20 and 0.40.

Findings: Methane production in the 15 roughages ranged from 13.4 to 34.4 liters/day with organic matter intake (**OMI**) ranging from 1.3 to 2.8 lbs/day (0.58 to 1.28 kg) and both variables were well related (Figure 1). *In vivo* organic matter digestibility (**OMD**) ranged from 46.4 to 64.3% and CH_4 production per kg OMD varied significantly from 38.6 to 63.7 liters. The latter findings suggest that CH_4 production is not a constant function of either OMI or digestible OMI despite the good overall relationship reported for OMI and CH_4 production (Figure 1).

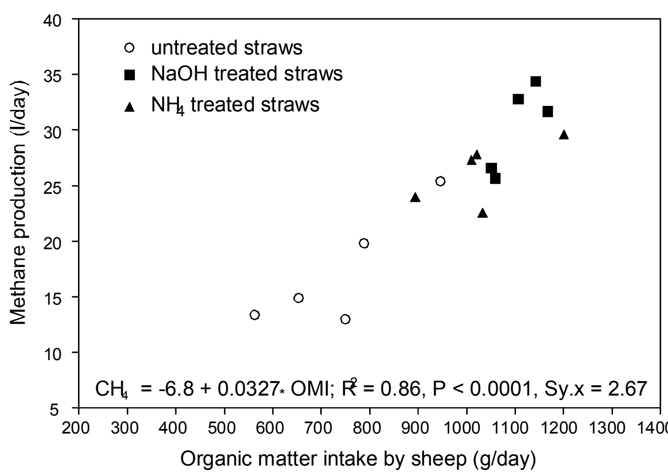


Figure 1. Relationship between organic matter intake and methane.

Across the 15 roughages, IVOMD measured after 24 hours of incubation varied from 34 to 61%. For the 15 roughages in this study, the substrate specific incubation times ($t_{1/2}$) found ranged from 15 to 22 hours of incubation. At $t_{1/2}$, acetate to propionate ratio varied significantly between 2.32 and 2.83 while EMP ranged between 0.21 and 0.49 but these estimates varied the different techniques employed for the estimation of EMP and there was little agreement in the ranking between the methods. There was a good agreement between measured and calculated OMI with the EMP estimate based on partitioning factor analysis. This factor is the ratio of *in vitro* organic matter truly degraded to gas volume concomitantly produced with the unit mg/ml. Calculated OMI where EMP estimates were based on purine analysis, microbial N determinations, and N-balances agreed less well with measured OMIs.

In all cases, relationships appear to be distorted by NaOH and NH_4 treatment. Higher OMI were observed in these treated roughages than was calculated. The *in vitro* estimates of IVOMD and EMP were based on treatment of the

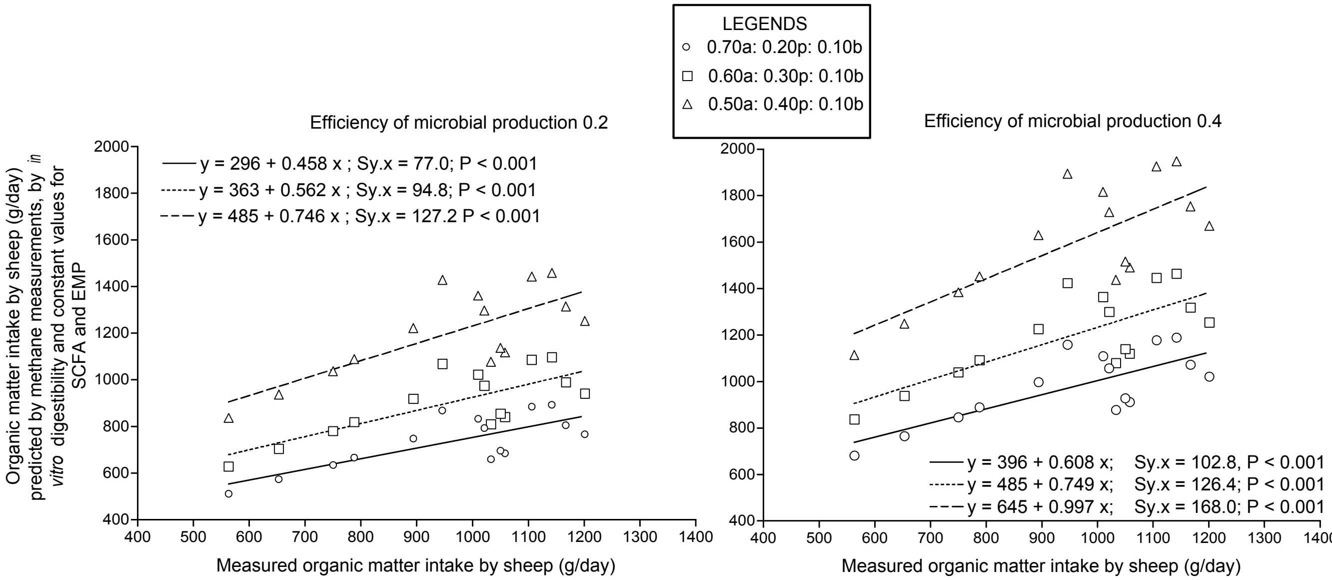


Figure 2. Organic matter intake measured and calculated by methane excretion, *in vitro* digestibility and constant *in vitro* fermentation characteristics.

incubation residue with neutral detergent solution to obtain a truly undigested residue. This treatment might have removed some partially hydrolysed and unfermented constituents in the alkaline treated straws resulting in an overestimation of IVOMD. In the calculations used for the prediction of OMI, overestimated IVOMD would result in lower values for calculated OMI.

When OMI was calculated by assuming constant SCFA proportions and constant EMPs the R^2 for the comparison of measured and predicted OMI (Figure 2) was 0.58 in all cases. While relationships were reasonable for OMI up to about 900 g/day there was little agreement between measured and calculated OMI above 900 g/day (2 lbs/day) (Figure 2). These findings suggest greater variations in SCFA and EMP in higher than in lower quality roughages.

Methane measurements *in vivo* in combination with measurements of *in vitro* fermentation characteristics such as SCFA proportions and efficiencies of microbial production provide a promising check for intake estimates based on marker techniques. This approach has also considerable potential for studying carbon efficiencies in grazing ruminants.

Future Direction: No further research is planned at Fort Keogh LARRL on this technique. Dr. Blümmel is pursuing this technique at his current location.

Relevant Publications:

Blümmel, M., E.E. Grings, A.R. Moss, and D.I. Givens. 2001. A mechanistic approach to the estimation of intake of ruminants by methane excretion and in vitro fermentation characteristics. Proc. West. Sec. Amer. Soc. Anim. Sci. 52:475-478.

Cited Publications:

Blümmel, M., P.S. Makkar, and K. Becker. 1997. In vitro gas production: a technique revisited. J. Anim. Physiol. and Nutr. 77:24-34.

Moss, A.R., D.I Givens, and P.C. Garnsworthy. 1994. The effect of alkali treatment of cereal straws on digestibility and methane production by sheep. Anim. Feed Sci. Technol. 49:245-259.

Cow Condition Score

Condition Score	Approximate Body Fat Percent	Appearance of Cow
1	4	Bone structure of shoulder, ribs, back, hooks and pins sharp to touch and easily visible. Little evidence of fat deposits or muscling.
2	8	Little evidence of fat deposits but some muscling in hindquarters. The spinous processes feel sharp to the touch and are easily seen, with space between them.
3	11	Beginning of fat cover over the loin, back, and foreribs. Backbone still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between the processes are less pronounced.
4	15	Foreribs not noticeable; 12th and 13th ribs still noticeable to the eye, particularly in cattle with a big spring of rib and ribs wide apart. The transverse spinous processes can be identified only by palpation (with slight pressure) to feel rounded rather than sharp. Full but straightness of muscling in the hindquarters.
5	19	12th and 13th ribs not visible to the eye unless animal has been shrunk. The transverse spinous processes can only be felt with firm pressure to feel rounded—not noticeable to the eye. Spaces between processes not visible and only distinguishable with firm pressure. Areas on each side of the tail head are fairly well filled but not mounded.
6	23	Ribs fully covered, not noticeable to the eye. Hindquarters plump and full. Noticeable sponginess to covering of foreribs and on each side of the tail head. Firm pressure not required to feel transverse process.
7	26	End of the spinous processes can only be felt with very firm pressure. Spaces between processes can barely be distiguished at all. Abundant fat cover on either side of tail head with some patchiness evident.
8	30	Animal taking on a smooth, blocky appearance; bone structure disappearing from sight. Fat cover thick and spongy with patchiness likely.
9	34	Bone structure not seen or easily felt. Tail head buried in fat. Animal's mobility may actually be impaired by excess amount of fat.

Adapted from Herd and Sprott, 1986.

USDA-ARS-Fort Keogh
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Name	Title
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Arnoldt, A. Butch	Farm/Ranch Hand
Arnoldt, Eddie	Equipment Mechanic
Austill, Diona	RL Secretary
Bellows, Sue	Bio. Lab. Tech.—Physiology
Bryan, Benny	Farm Manager
Clendenen, Janice	Administrative Clerk
French, Larry	Bio. Lab. Tech.—Genetics
French, Mary Ellen	Office Automation Assistant
Geary, Tom	Reproductive Physiologist
Grings, Elaine	Range Animal Nutritionist
Haferkamp, Marshall	Rangeland Scientist
Harris, Rick	Farm/Ranch Hand
Heitschmidt, Rod	Research Leader/Rangeland Ecologist
Hendry, Lee	Maintenance Worker
Hould, Byron	Assistant to the Superintendent
Howard, Jim	Farm/Ranch Hand
Kessler, Jim	Farm/Ranch Hand
Klement, Keith	Rangeland Scientist III
Leidholt, Mish	Rangeland Technician
Life, Gene	Safety and Occupational Health Specialist
Lockie, Sandra	Administrative Aide
MacNeil, Mike	Quantitative Geneticist
Mott, Tom	Agric. Tech. II—Genetics
Murphy, Cheryl	Bio. Lab. Tech.—Range
Nunn, Jerry	Farm/Ranch Hand
Perry, George	Bio. Lab. Tech.—Physiology
Phelps, Dave	Research Associate—Physiology
Reil, Sue	Bio. Lab. Tech.—Nutrition
Reisenauer, Vicki	Statistician
Roberts, Andy	Reproductive Physiologist
Scheid, Lynn	Farm/Ranch Hand
Shipp, Brooke	Bio. Lab. Tech.—Physiology
Smith, Phil	Heavy Equipment Operator
Stanton, Sharon	IT Specialist
Strobel, Kenny	Maintenance Supervisor
Taylor, Cody	Farm/Ranch Hand
Vermeire, Lance	Rangeland Ecologist
Watts, Jim	Farm/Ranch Hand

We're on the web!
www.larrl.ars.usda.gov

Fort Keogh
Livestock and Range Research Laboratory

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Fun For Kids
New Construction

NEW! Download your copy of the July Fort Keogh Researcher!

LARRL Upcoming Events.

On August 9, we held a groundbreaking ceremony for the new technology transfer center and labs to be built soon and held an open house with tours. Above is a picture of the VIP's officially performing the groundbreaking! For more pictures, click here.

Fort Keogh is a 55,000 acre USDA - Agriculture Research Service (ARS) rangeland beef cattle research facility. It is 1 of 14 research locations that make up the 8 state Northern Plains Area of ARS. It is run in cooperation with the Montana Agricultural Experiment Station, the agriculture research component of Montana State University.

Our Mission is to research and develop ecologically and economically sustainable range animal management systems that ultimately meet consumers needs.

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