PROGRESS REPORT 1997

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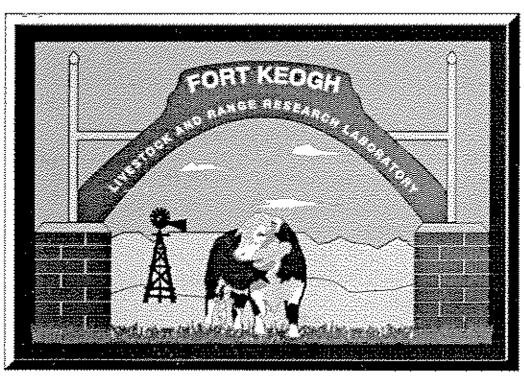

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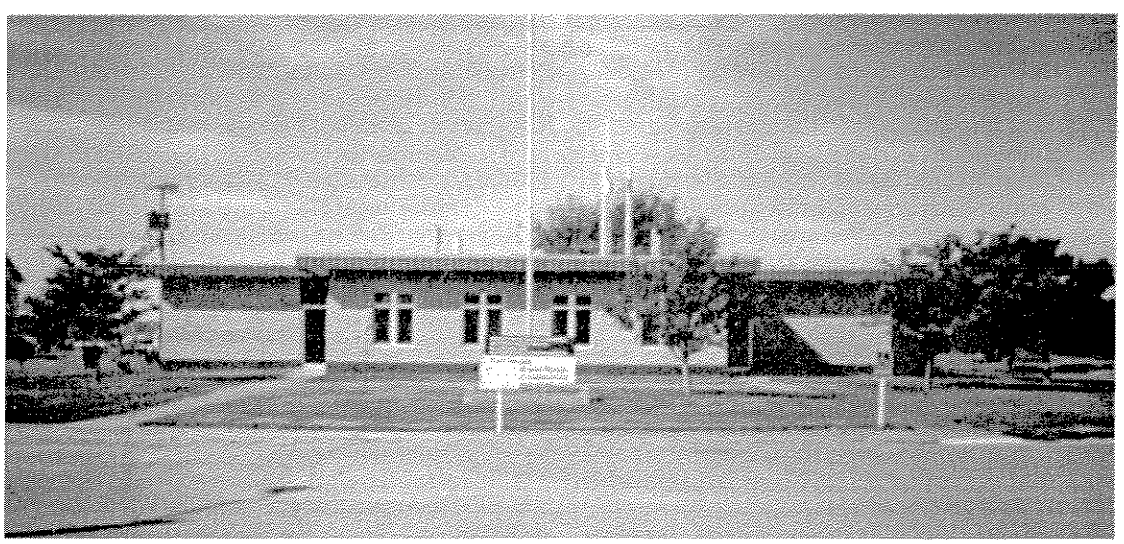
Front Page Picture from ARS Magazine, Nov. 1991.

Forward

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

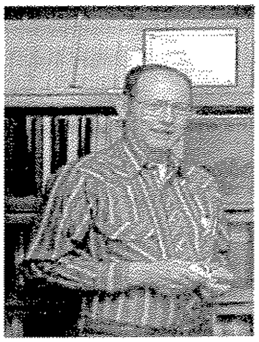
The broad mission of the Laboratory is to develop ecologically and economically sustainable range livestock production system that ultimately meet consumer needs. Research is multidisciplinary revolving around four broad disciplines: 1) rangeland management and ecology; 2) beef cattle genetics; 3) range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

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



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

The Authors



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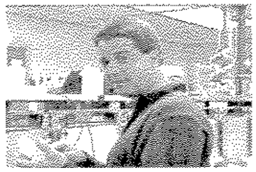

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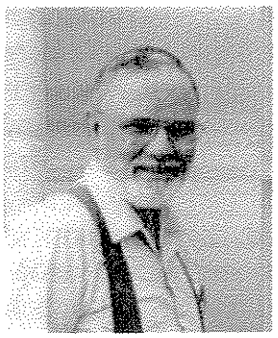

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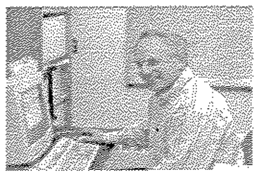

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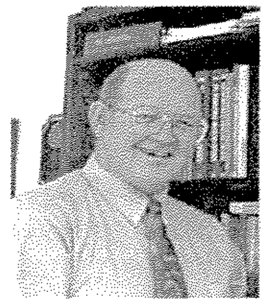

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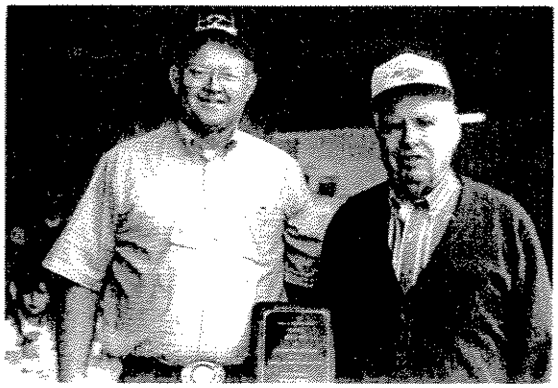


Rod Heitschmidt, Research Leader, and
Bob Smith, Producer of the Year
Fort Keogh Open House Sept. 1996

Producer Recognition Award

Robert M. Smith was born July 8, 1925, in Tribune, Kansas; the son of A.E. and Margaret Smith. Pioneers in Western Kansas, the Smith family homesteaded in 1885. Schooled in Tribune and Kemper Military School in Boonville, Missouri, Bob went into the army and served in Guam and the Philippines. He attended Colorado State University, majoring in animal science. Bob married Alberta Knox in Denver in June of 1949 and moved to the newly purchased ranch east of Colorado Springs at Rush.

Water management was a primary concern on the 50,000 acre watershed on the ranch. Smith worked with the Soil Conservation Service to build dikes, dams, and reservoirs to irrigate hay meadows and spread the creek over a large area, slowing the water and allowing the sediment to settle in surrounding gullies.

The cow herd was Hereford and Bob used CK Hereford Bloodlines from Brookville, Kansas, for many years, eventually changing to crossbreeding with blacks. He was actively involved in many organizations and served as president of the Pikes Peak Cattlemen during this time.

Like his father, Bob believes it is more efficient and profitable to operate several ranches of what might be termed smaller size than a really big spread concentrated in one geographic location.

The Smiths leased some ranches in Texas in 1947, but droughted out in 1953 and moved 1300 pair to the leased Trail Creek ranch on the Power River. In 1954 they bought the ranch and in 1961 obtained the Wibaux ranch and the 55,000 acre Babbitt Ranch in Garfield County.

As manager of these Montana ranches as well as the Colorado ranch, Bob moved his family to Miles City in 1969.

Smith Cattle has farming, feedlots and an integrated ranching enterprise headquartered in Tribune, KS. Bob and his brothers Joe and Don were awarded the Environmental Stewardship Award of the National Cattlemen's Association in Reno, Nevada, in 1994. This was a proud moment in a lifetime of ranching.

Primarily a steer operation, steer calves are bought by order buyers at auction barns throughout eastern Montana and western North Dakota. While most of the cattle they background are put together from these sales, several hundred are contracted from area feeder-calf producers. The Cohagen and Wibaux units have 1100 black baldy cows and Smith uses Amerifax bulls (5/8 Angus and 3/8 Friesian). In the past few years Bob has used Angus bulls purchased from Quirk Cattle, Hastings, Nebraska. In the fall the yearlings are sorted and moved to the Oxtown Feed Yard in Tribune, KS or sold at private treaty or, recently, at video auction.

Bob has demonstrated a deep appreciation for research to improve methods of production of beef cattle as well as other phases of agriculture. For several years he has served on the Montana Stockgrowers Marketing committee and serves as a member of the Liaison Committee for the Fort Keogh Livestock and Range Research Laboratory. For three years he has sent 275 steers yearly to Fort Keogh from the ranch for forage and grazing management research.

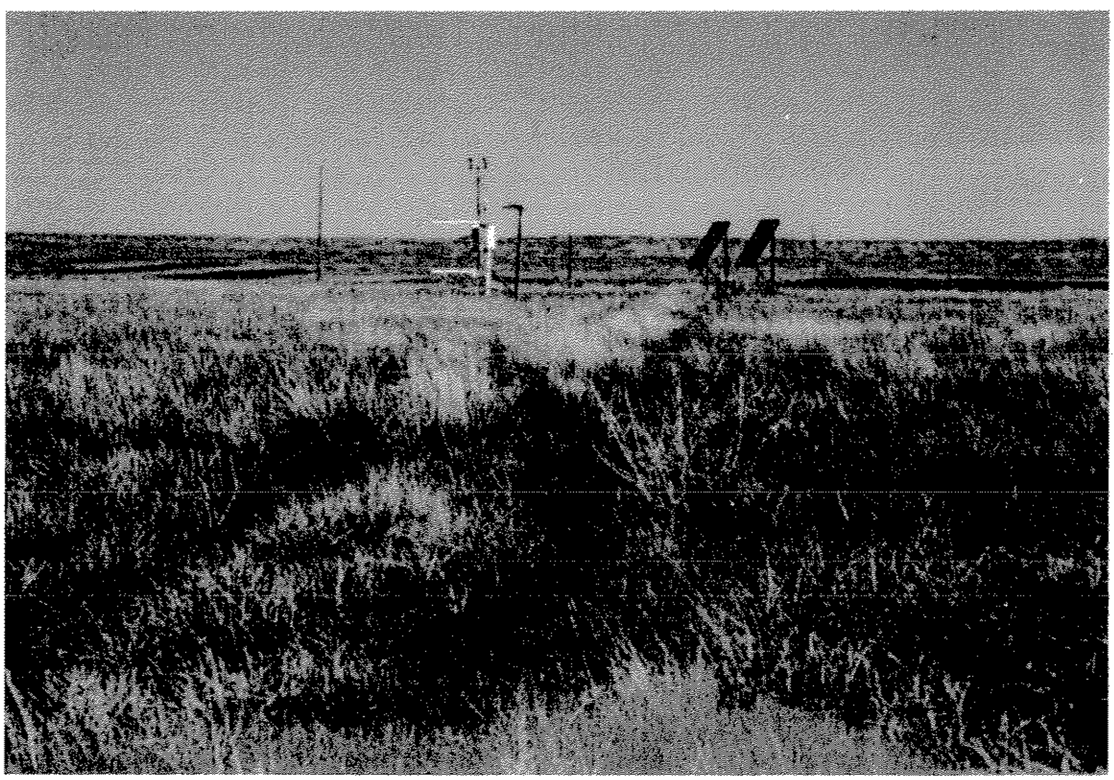
Bob and Alberta celebrated their 47th wedding anniversary this year. They have four children, Marcia, Patricia, Nancy, and David. Bob and David and Jody, and Tom and Nancy Horn are continuing the Smith ranching tradition that has existed for over 100 years.

A. Rangeland Productivity

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

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

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



Establishment and Spread of Annual Brome

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

Problem: Developing management tactics to best use or control alien annual bromes in the Northern Great Plains requires understanding the mechanisms and processes that allow a brome invasion. The goal of these studies was to investigate environmental effects on seed germination and seedling development of annual bromes.

Procedures: Germination studies were conducted in controlled environments. Seed collection dates, storage temperatures, and moisture content varied. Seeds and seedlings were incubated in regimes of temperature, light, and water stress to simulate naturally occurring environmental conditions.

Findings: The life cycle of annual bromes allows them to establish and spread on rangelands. Seeds germinate in late summer and early fall, and emerged seedlings overwinter and resume growth in early spring. In our studies, Japanese brome seeds germinated over a wide range of temperatures. We found a percentage of seeds, which did not fall from seedheads or did not germinate in fall (before late September), entered a dormant condition. This dormant state may last through winter, spring, and summer. Thus, seedlings emerging in August and September likely come from two seed crops, the current one and the one from the past year.

We found Japanese brome seed germinated when harvested green in mid-June. Thus, Japanese brome hay should only be fed on brome infested areas to reduce spread into uninfested areas.

A shortage of water during seed germination or seedling emergence may severely reduce Japanese brome seedling density. We found Japanese brome seeds and seedlings germinated and grew better than those of downy brome without water stress. However, downy brome seeds and seedlings germinated and grew better with water stress. These findings explain why these two annual bromes grow together on moist sites (e.g., moderate slopes), but downy brome dominates on dry sites (e.g., ridge tops).

Future Direction: Additional studies on brome seed germination and seedling development are not planned. Data from past studies are being analyzed.

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

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

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

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

Forage Production of Annual Brome

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

Problem: Developing grazing management tactics to best use alien, annual brome infested ranges in the Northern Great Plains requires understanding factors affecting their annual variation in spring forage production. The goal of these studies was to investigate effects of managerial interventions on production of annual bromes.

Procedures: Samples were collected from a series of pastures at Fort Keogh from 1984 to 1990. Forage standing crops were estimated annually in all pastures just before the grazing season by hand harvesting all herbage above a 1" stubble height in fifteen plots per pasture. Because clipping dates varied among years, all data were adjusted to 5 June.

Findings: Forage production of Japanese and downy bromes is erratic from year to year. From 1984 through 1990 at Fort Keogh, production of annual grasses ranged from 25 pounds per acre in 1988 to 500 pounds per acre in 1990. Annual brome contributed 60 to 90% of this amount. Crude protein of Japanese brome ranged from 13 to 17% in seedlings to 2 to 3% in mature forage, whereas seedheads may contain 8 to 12% crude protein. For comparison, 9% crude protein is the suggested level for a 1,000 pound cow with average milking ability consuming 22 pounds of forage per day, during the first 90 to 120 days of lactation. These forage characteristics suggest early spring is the optimum period for livestock production on brome infested ranges.

Variation in the amount of rainfall and available soil nitrogen are probably the major causes for the erratic behavior in annual forage production. Forage quality will also be affected by the seasonal distribution and amount of precipitation, declining most rapidly as the soil dries and plants begin to mature. In contrast, during a cool-wet growing season, forage quality may remain high for longer periods as plants remain green and continue to produce new shoots.

One of the greatest challenges in managing brome infested ranges is predicting when early spring forage production of annual bromes will be adequate to allow grazing that will not severely affect associated perennial grasses. In many years, annual bromes are only 3" to 4" tall and tillering, and in other years they are 12" tall and tillering.

Future Direction: Studies to improve our understanding of the population dynamics of annual brome are continuing. Developing a better understanding of their relationship to soil water, soil nitrogen, and seedling density in the Northern Great Plains will help make better management decisions. This information is needed to develop user friendly Decision Support Systems to aid in management of brome infested ranges.

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

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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.

Influence of Japanese Brome on Western Wheatgrass

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

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

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

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

Removal of Japanese brome increases forage production of western wheatgrass, but decreases total forage production. These results occurred over a 4-year period of varying precipitation and associated vegetation. We think we have answered the question "How much does Japanese brome impact western wheatgrass?" Now it is up to the individual producer to determine if the loss of western wheatgrass production is large enough for concern, or can they effectively manage the increased total forage production resulting from the presence of brome. One must factor in both the erratic year to year production and the rapidly declining forage quality of annual bromes.

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

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

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

Haferkamp, M.R., R.K. Heitschmidt, and M.G. Karl. 1997. Influence of

Japanese brome on western wheatgrass yield. J. Range Manage. 50:44-50.

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

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Simulated Grazing of Japanese Brome

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

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

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

Findings: In 1991, plants remained vegetative throughout. Clipping in any form reduced production of roots, herbage, and total biomass. Increasing the intensity of clipping significantly reduced herbage and total biomass, and although similar trends occurred with root biomass, differences were not significant. Increasing the frequency of clipping from every 2 weeks to weekly did not significantly reduce biomass production.

In 1992, plants produced reproductive shoots. Increasing intensity of clipping significantly reduced total herbage weight and reduced total biomass for all but the plants clipped to 6" every 2 weeks. Root weights were similar for nonclipped controls and both clipping frequencies at 6", but weights were much less for plants clipped at 3". Weight of inflorescences was greatest for nonclipped controls. Frequency of clipping did not generally affect any component as much as intensity of clipping.

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

Future Direction: This study, with plants producing reproductive shoots, is being repeated in winter and spring 1996-1997. Developing of grazing management tactics to reduce brome on infested ranges in the Northern Great Plains is a long-term goal.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

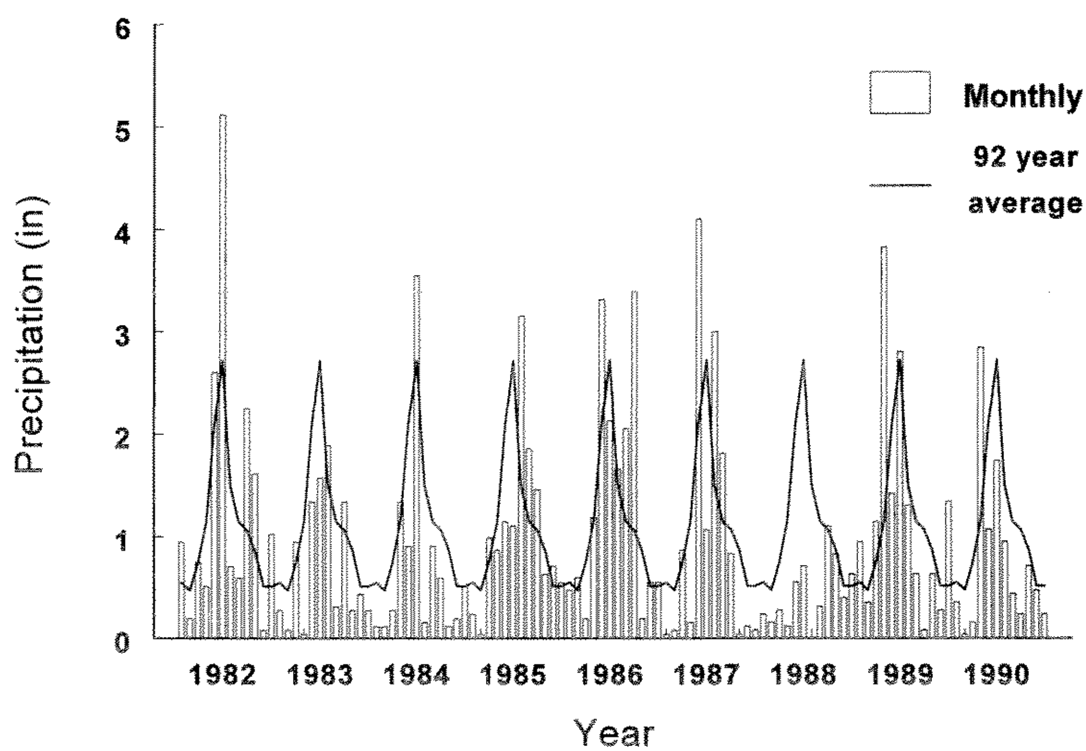


Figure 1. Actual (Jan.-Dec. 1982-1990) and long-term (92 year) average precipitation for Miles City, Montana.

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

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

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

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

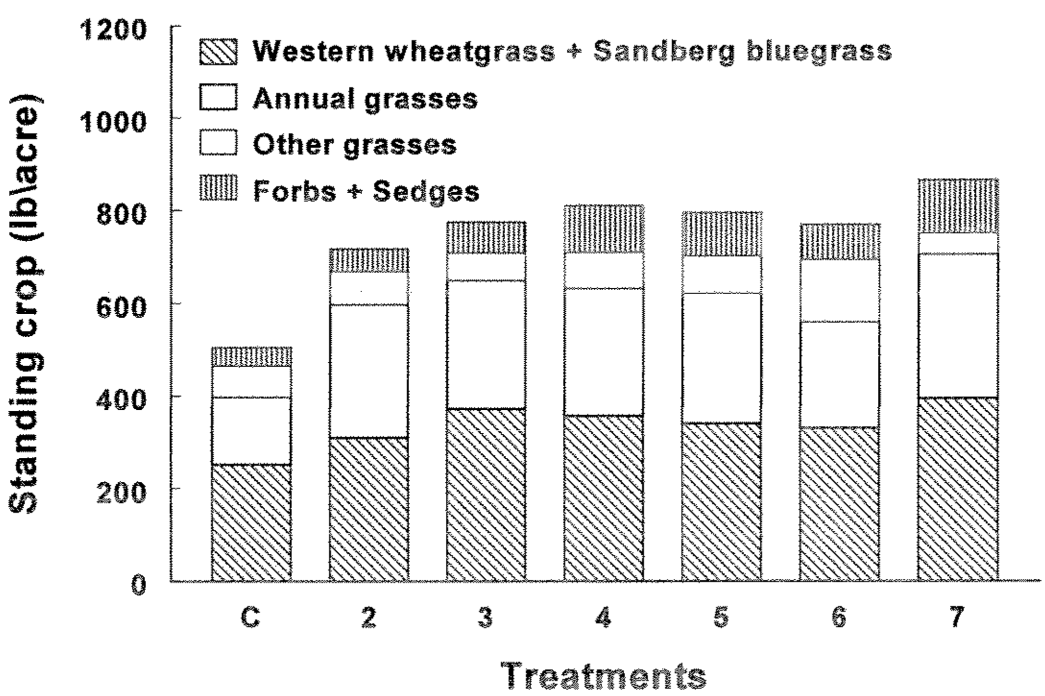


Figure 2. Current year forage production by treatment (see Table 1) averaged across two sites and eight years.

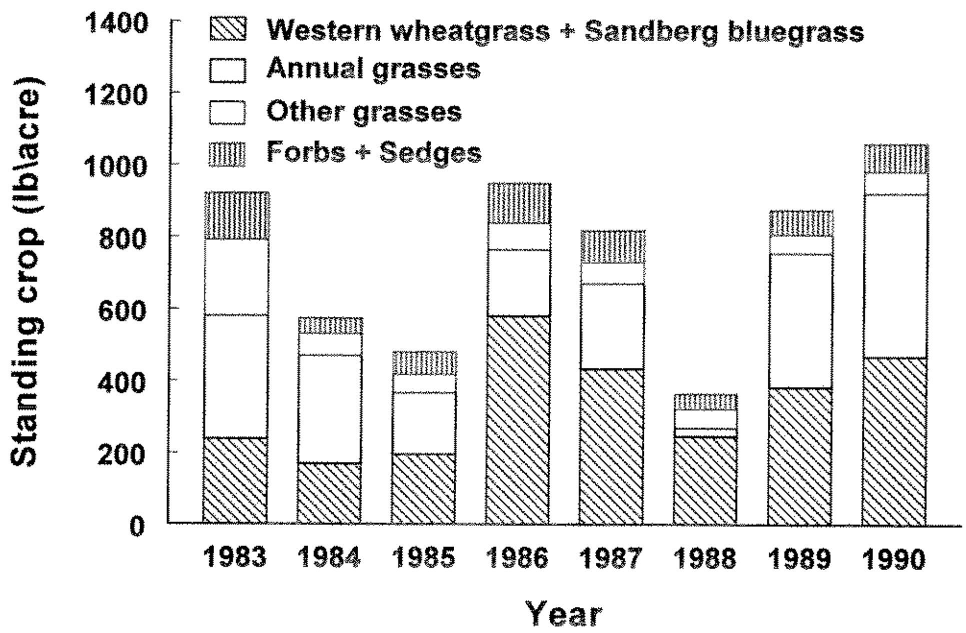


Figure 3. Current years forage production by year averaged across two sites and seven treatments (see Table 1).

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

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

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

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

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

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

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

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

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

Seed Bank Dynamics in a Northern Great Plains Rangeland

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

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

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

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

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

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

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

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

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

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

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

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

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

Mineral Dynamics of Forages During the Growing Season

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

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

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

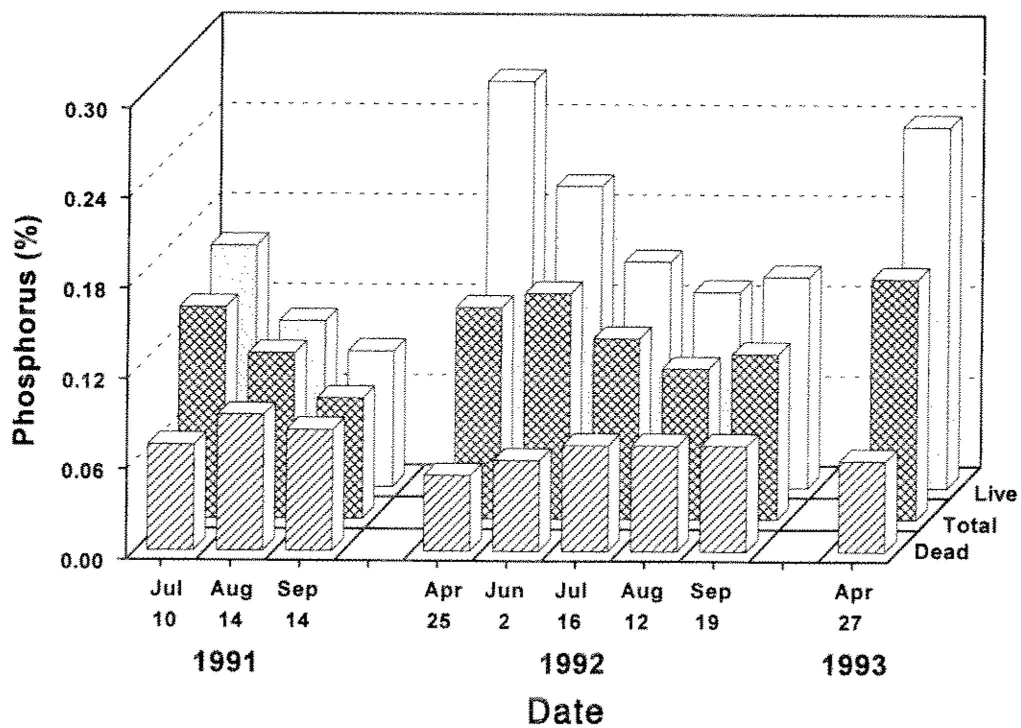


Figure 1. Live, dead, and whole plant phosphorus concentrations (% of dry matter) for western wheatgrass on 9 dates.

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

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

Soil type affected several nutrients. However, these effects were partly related to effects on the make-up of species groupings and on live:dead ratios. Nutrients that were most likely to be in quantities less than that recommended for beef cattle were phosphorus, potassium, sodium, zinc, and copper. We conclude that the relative amount of live and dead was a major influence on whole-plant nutrient content for all macrominerals except sodium. This was less apparent for the trace minerals. The relative amounts of live and dead tissue may be used to assist in determining mineral levels in cattle diets, especially for phosphorus and potassium.

Future Directions: This project was completed.

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

Measuring Carbon Fluxes over Northern Great Plains Rangelands

M.R. Haferkamp and R.K. Heitschmidt

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

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

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

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

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

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

Findings: Measurements were begun in 1996. We are in the process of reducing data and conducting laboratory analyses.

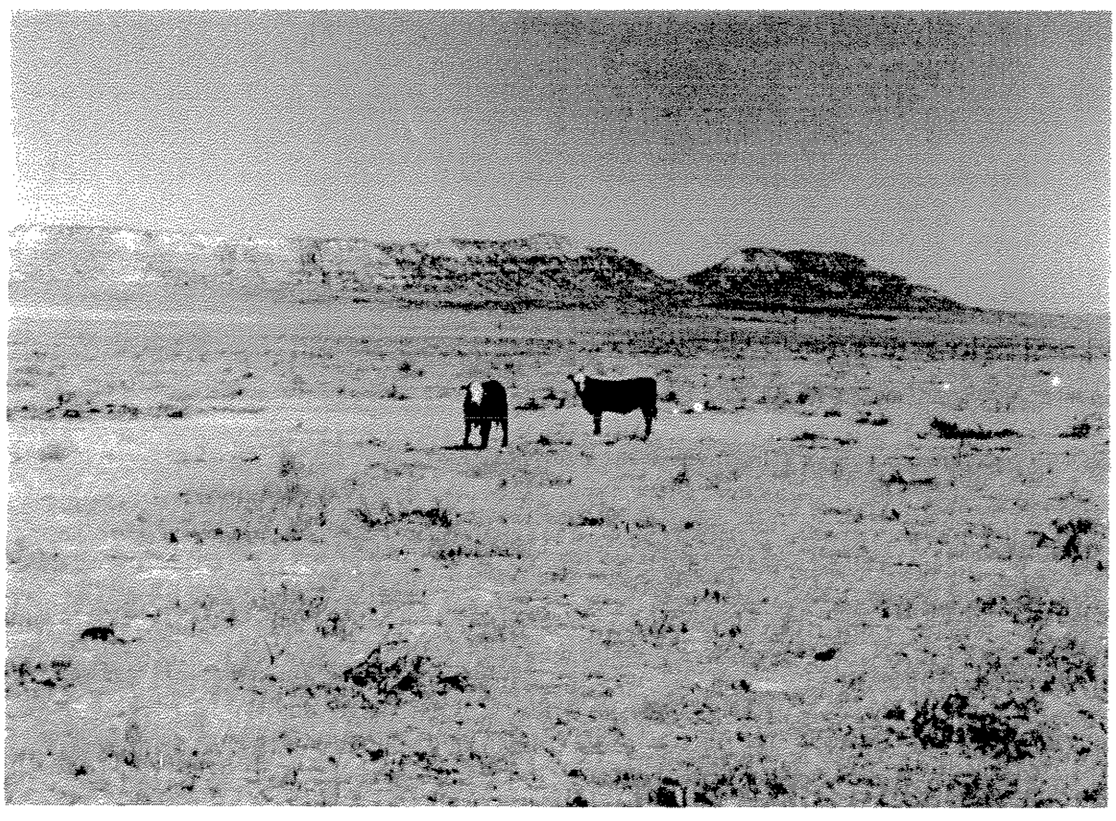
Future Direction: These studies will be continued through at least 1998. Information from these studies should provide improved estimates of the contribution of Northern Great Plains ranges and associated grazing practices to carbon dioxide flux and ultimately to global warming.

Relevant Publications: None to date (July 1997).

B. Management Strategies for Grazing Livestock

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

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



Impacts of Various Livestock Grazing Strategies on Northern Great Plains Rangelands

R.K. Heitschmidt and M.R. Haferkamp

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

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

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

A. Moderately stocked

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

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

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

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

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

   This treatment uses high performance grazing (HPG) tactics. In contrast to HUG tactics, HPG tactics cause greater numbers of preferred than non-preferred plants to be defoliated. However, because of the short grazing period, it is perceived that intensity of defoliation of the 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 Oct. 13 until March 21. In this system, the herd grazes each of the three pastures once during the dormant season for 57 days. As in treatment 1, the first pasture grazed each year rotates among pastures so that the pasture grazed first is the one grazed last the next year and grazed second the year thereafter. Thus, each pasture is only grazed at the same time of the year every third year.

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

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

B. Heavily stocked

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

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

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

Relevant Publications: None to date (July 1997).

Diet Quality of Suckling Calves and Mature Steers on Rangelands

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

Problem: Determining the quality of diet eaten by free-ranging livestock is often done using esophageally cannulated animals. Despite much research on the diets of cattle, little is known about diets of suckling calves. Studies with suckling calves and cows show variable, but different, quality of diets selected by the calf and cow. The goal of this study was to determine if suckling calves would select diets of higher quality than mature cattle and if this effect depends on season of the year. This information would aid in evaluating weight change patterns in these cattle throughout the year.

Procedures: Diets were collected from esophageally cannulated suckling calves or from steers that were two-years-old or older. Sampling was conducted in June, July, September, October, and November in each of two years.

Findings: Suckling calves selected diets of higher quality than did mature steers early in summer when calves were receiving much of their nutrient intake from milk, but not at later times. This seasonal difference may be caused by learning behavior, changes in forage quality, or increased forage intake by calves. Similarity across animal ages and years during October and November may be related to the lack of opportunity to select a higher quality diet when all available herbage is of poor quality.

Young calves may have more time to be selective in their foraging due to the consumption of milk, a high quality food. As milk intake declines, forage consumption increases and the calf may have less time available for diet selectivity.

In another study, suckling calves gained weight at a relatively constant rate from April through September, even though forage maturity advanced and milk consumed by the calf declined as season advanced. In contrast to the calves, their dams lost weight and body condition as the season advanced. Moreover, yearling cattle had small or negative live weight gains by early August. The combination of a small amount of milk and a higher quality diet selected by suckling calves may help explain the differences in live weight

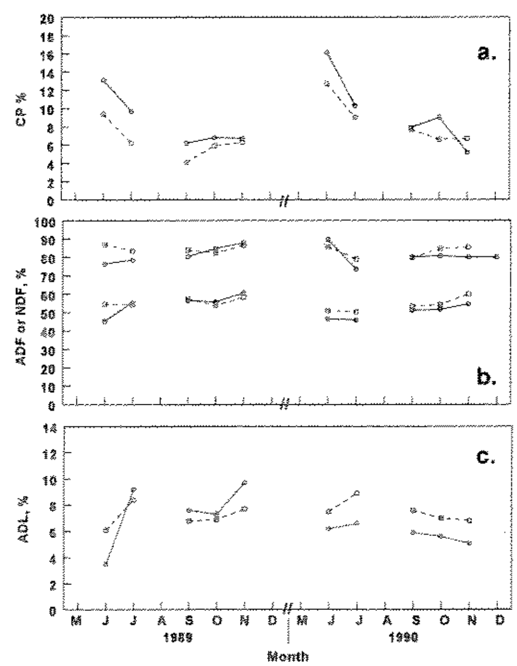


Figure 1. Crude protein (CP), neutral detergent (NDF) and acid detergent fiber (ADF), and acid detergent lignin (ADL) expressed on an organic matter basis in the diets of steers (broken line) and suckling calves (solid line).

gains that occur between mature animals and suckling calves grazing summer range.

Future Direction: Additional studies are being conducted to evaluate differences in both botanical and chemical composition of cattle of a variety of ages. Monthly diet samples from May through November were collected using suckling calves, lactating cows, yearling heifers, and mature steers. Laboratory analysis is ongoing.

Relevant Publications: Grings, E.E., D.C. Adams, and R.E. Short. 1995. Diet quality of suckling calves and mature steers on Northern Great Plains rangelands. J. Range Manage. 48(5):438-441.

Livestock Performance on Improved Cool-Season Forages

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

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

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

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

Yearling cattle will graze the pastures from mid-April to mid-June. They will be weighed and standing crop clipped monthly. Diet samples will be obtained and analyzed for species composition and quality. Forage samples will be dried, weighed, and analyzed for quality. Environmental variables will be monitored on site.

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

Findings: Pastures were grazed with eight yearling steers from May 9 to June 12, 1997. The spring was relatively dry resulting in poor plant growth and reduced weight gains. Standing crops were 350 to 450 lb/acre of Luna, 425 to 650 lb/acre of Rosana, and 725 to 900 lb/acre of Hycrest. The steers gained only 0.3 lb/day. The Luna stands also died out on ridge tops probably due to lack of moisture the previous summer and fall.

Future Directions: These studies will be repeated in 1998 and 1999. Additional species will be seeded in other locations on the station for future evaluation.

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

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

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

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

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

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

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

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

Grazing and Drought Management

R.K. Heitschmidt, M.R. Haferkamp, and A.L. Hild

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? Current Great Plains livestock grazing intensities during and after drought are most likely heavier than those under which these rangelands were subjected to historically. For example, it might be reasonable to assume that the large bison herds that grazed these rangelands would have either migrated out of a drought region and/or died during periods of severe drought. More importantly, it seems reasonable that grazing intensity following drought would have been lighter than today since it would have taken time for the bison to migrate back to a region and/or to repopulate through normal reproduction processes. Thus, a period of rest following drought may be of benefit to Northern Great Plains rangelands. The goal of this research was to examine the impacts of grazing during and after drought on these rangelands.

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

Findings: Surprisingly, results showed that grazing treatment did not affect total forage. Total forage production was equal whether plots were grazed or rested during or after drought. However, grazing treatment did affect production of both the warm season perennial and annual grasses. Grazing during drought tended to decrease warm season grass production in the years after the drought regardless of whether plots were grazed or rested the year after the drought. However, the response was somewhat different for the annual grasses, such as Japanese brome and cheatgrass. Grazing during drought only tended to reduce production of annual grasses if plots were also grazed the year following drought.

The most important factor affecting forage production during the years 1994 through 1996 was the drought of 1994. Averaged across the three years and the three grazing treatments, herbage production in the drought plots averaged 1825 lb/acre whereas it averaged 2241 lb/acre in the non-drought plots. Production was greater in both 1994 and 1995 in the non-drought than drought plots, but there were no differences in 1996, two years after the drought.

This study indicates that short-term grazing during early June and July during and after a late spring, entire summer, and early fall drought has minimal impact on total herbage production. However, some changes in species composition can be expected.

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

Relevant Publications: None to date (July 1997).

Management Strategies for Grazing Yearling Cattle

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

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

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

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

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

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

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

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

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

both forage intake and digestibility, thus accounting for the lack of response.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

	Sire Growth Potential	
Efficiency	High	Moderate
	1.5	1.4

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

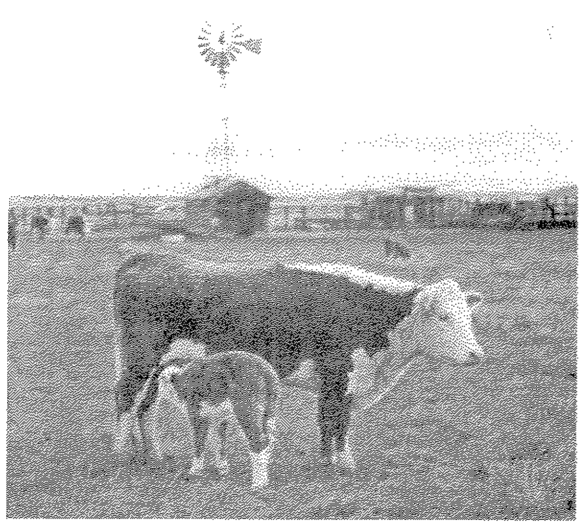
C. Establishing Female Fertility

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

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

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

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



Time of Breeding of Replacement Heifers

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Relevant Publications: None to date (July 1997).

Treatment of Prepuberal Heifers with Melatonin

R.A. Bellows and J.B. Hall

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Relationships of Body Composition and Metabolic Status to Puberty in Heifers

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

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

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

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

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

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

Initiation and Synchronization of Estrous Cycles in Peripuberal and Postpartum Cows

R.E. Short and M.A. Lammoglia

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

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

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

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

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

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

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

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

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

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

Future Directions: These experiments are continuing.

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

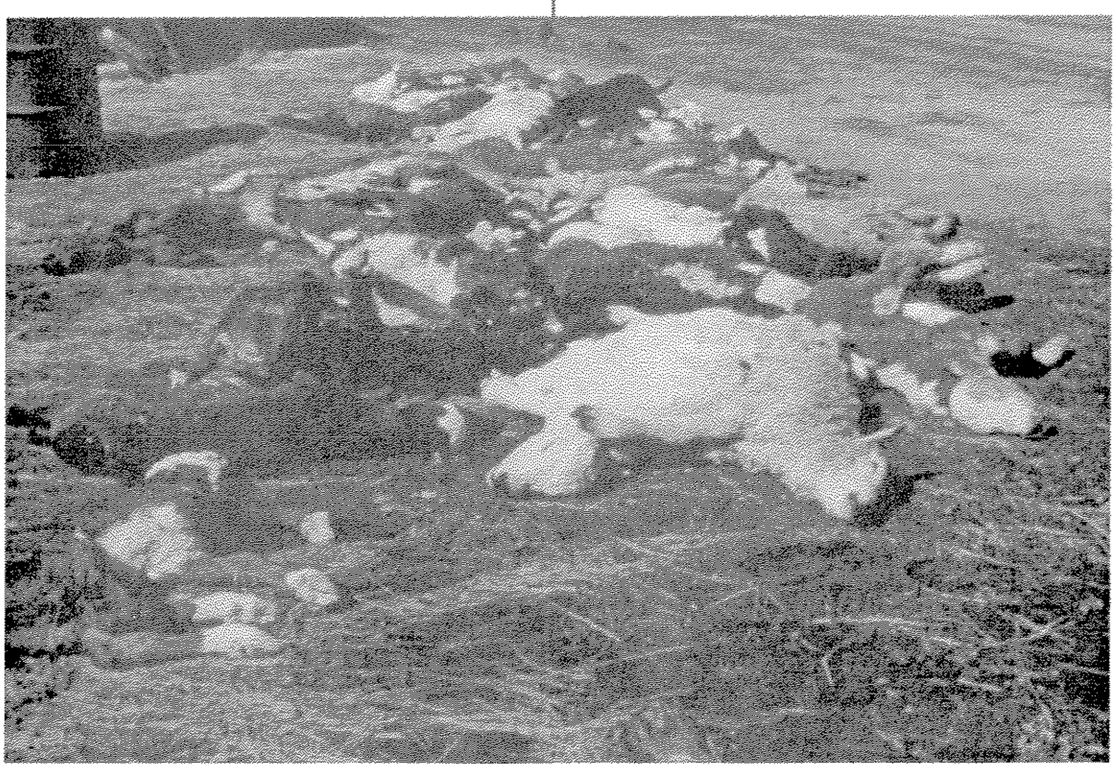
Rasby, R.J., M.L. Day, S.K. Johnson, J.E. Kinder, J.M. Lynch, R.E. Short, R.P. Wettemann, and H.D. Hafs. 1998. Luteal function and estrus in peripubertal beef heifers given an intravaginal progesterone releasing device with or without a subsequent injection of estradiol. Theriogenology (In press).

D. Calving Difficulty and Calf Survival

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

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

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



Joint Effects of Fetal and Maternal Genotypes on Calving Difficulty

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

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

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

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

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

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

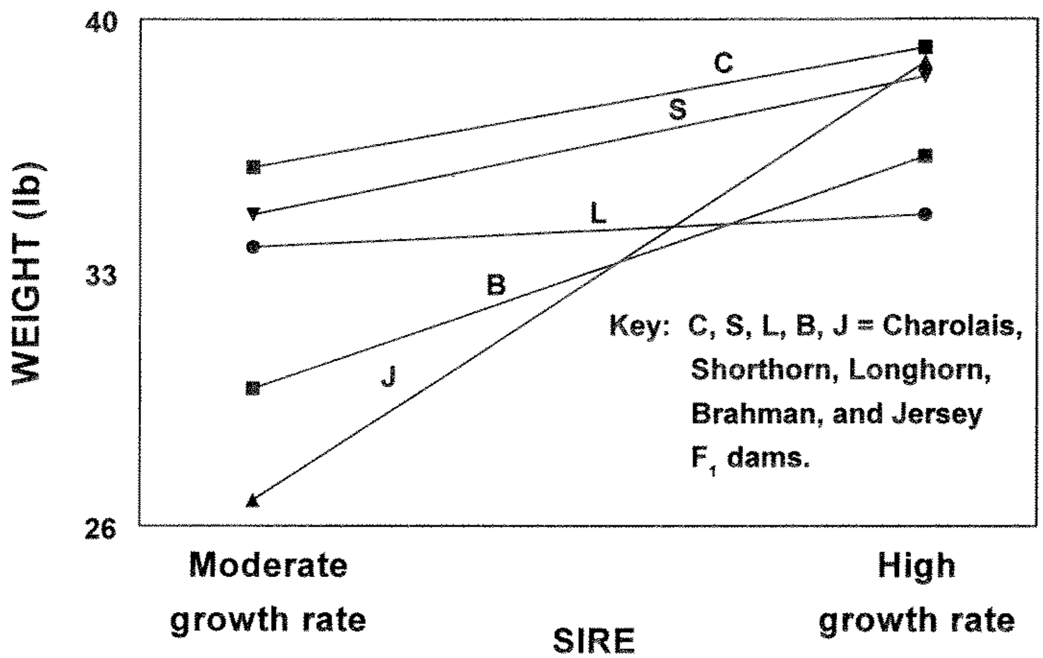


Figure 1. Fetal genotype by maternal uterine environment effects on eviscerated fetus weight at 231 days of gestation.

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

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

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

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

Can Balancing Birth Weight and Growth Improve Calving Ease?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Calving Difficulty in Brahman-Cross Heifers

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

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

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

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

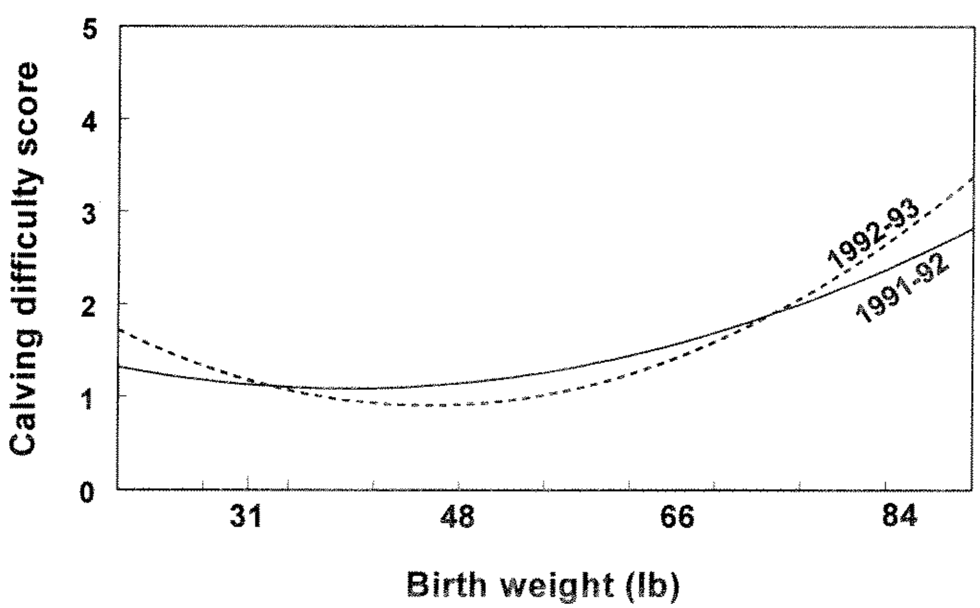


Figure 1. The relationship between calving difficulty score and birth weight of calves.

Findings: Data obtained at the end of the breeding season were of little value in predicting calving difficulty. However, calf birth weight was a consistently important cause of calving difficulty in this environment where birth weights are low. Severity of calving difficulty was increased with very low birth weights, lowest with intermediate birth weights and highest with heaviest birth weights. Calving difficulty was least severe when birth weight was about 50 pounds.

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

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

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

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

Effects of Gestation Exercise

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

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

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

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

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

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

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

Effects of Relaxin on Calving Difficulty

R.W. Caldwell and R.A. Bellows

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

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

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

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

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

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

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

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

Dietary Protein Effects on Calving Difficulty and Maternal Hormone Patterns

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

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

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

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

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

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

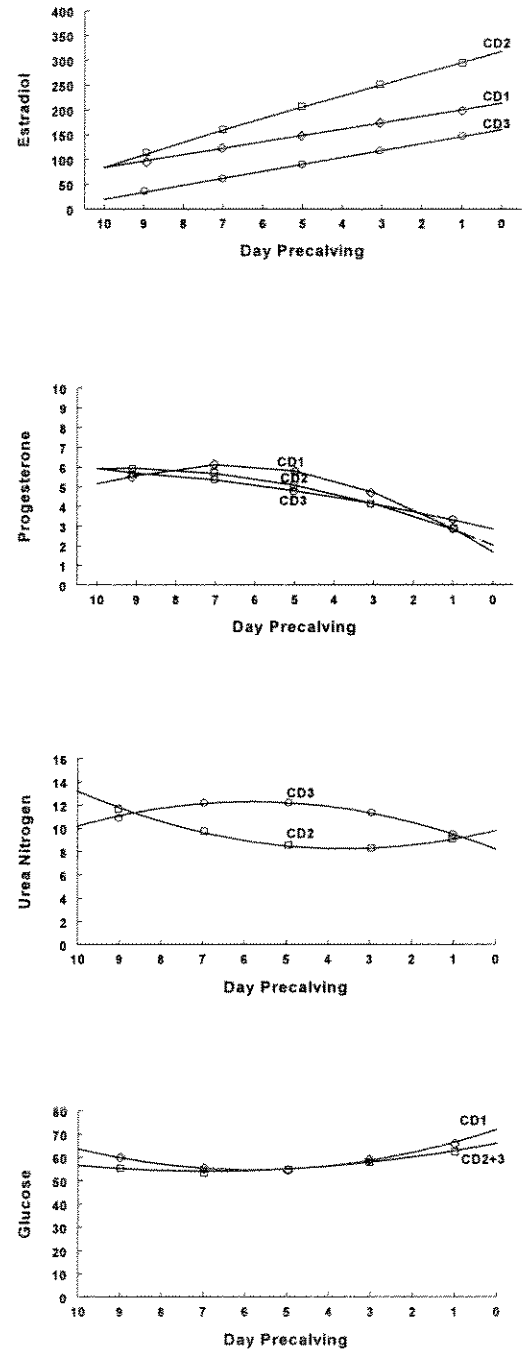


Figure 1. Blood concentrations of compounds before calving shown by calving difficulty score.

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

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

Relevant Publications:

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

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

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

M.A. Lammoglia and R.A. Bellows

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

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

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

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

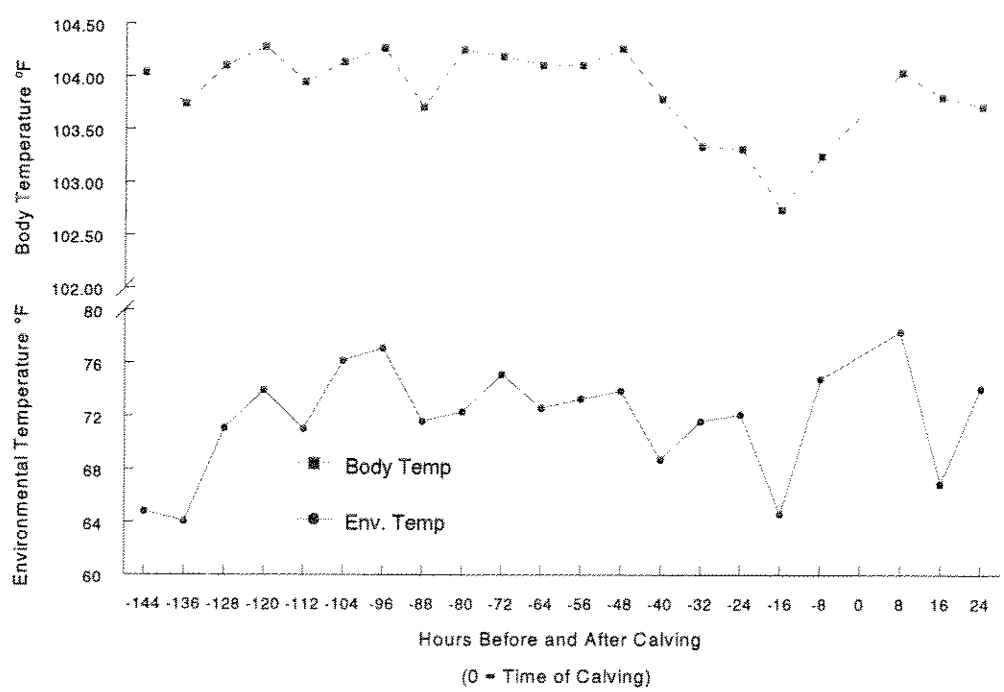


Figure 1. Body and environmental temperatures as related to time of calving.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

M.A. Lammoglia and R.A. Bellows

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

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

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

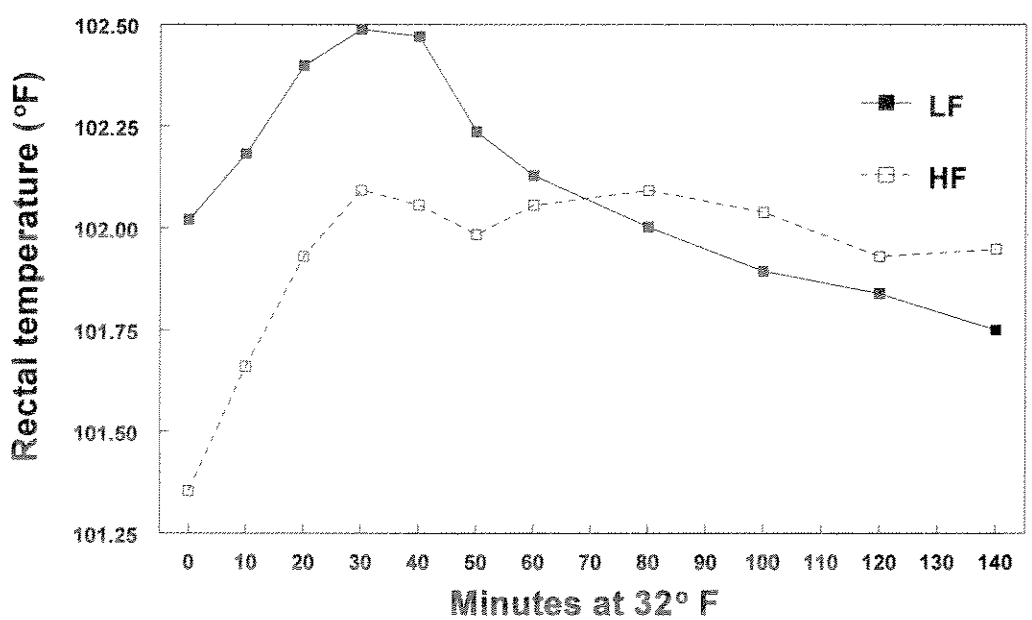


Figure 1. Rectal temperature of newborn calves exposed to 32°F for 140 minutes and born to cows receiving 1.7% (LH) or 4.9% (HF) dietary fat 53 days before calving.

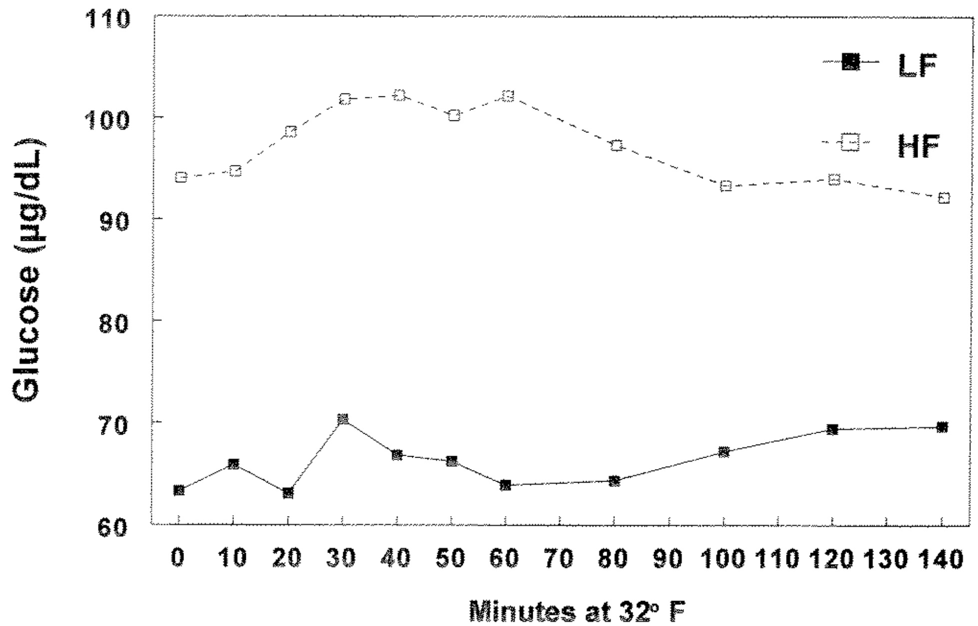


Figure 2. Plasma glucose concentrations of newborn calves exposed to 32°F for 140 minutes and born to cows receiving 1.7% (LH) or 4.9% (HF) dietary fat 53 days before calving.

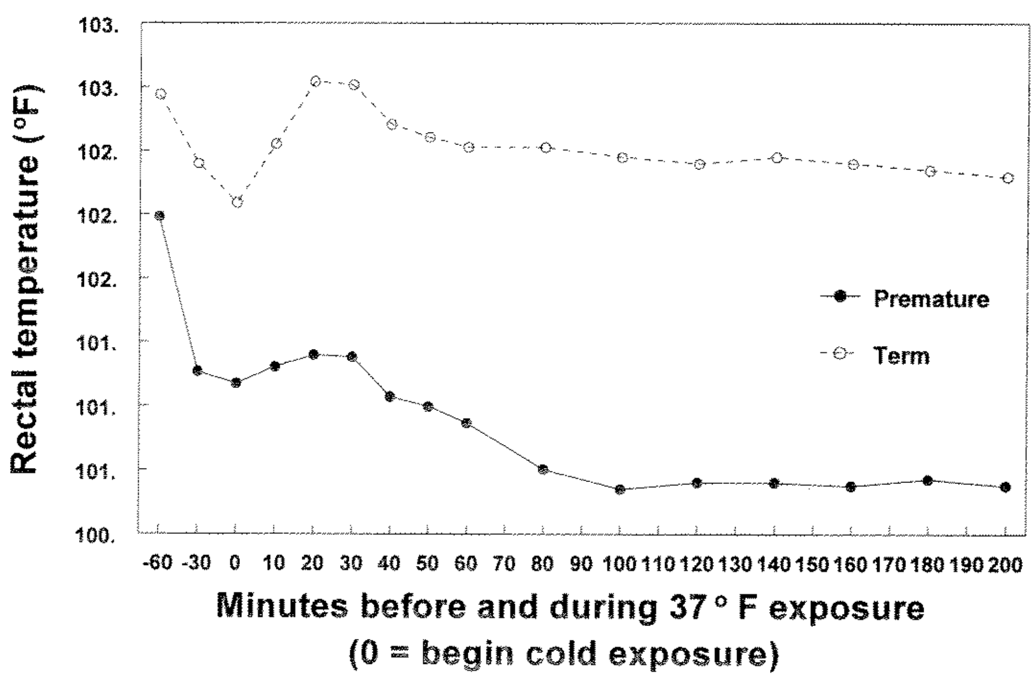


Figure 3. Rectal temperature of newborn mature and premature calves exposed to 37°F for 200 minutes.

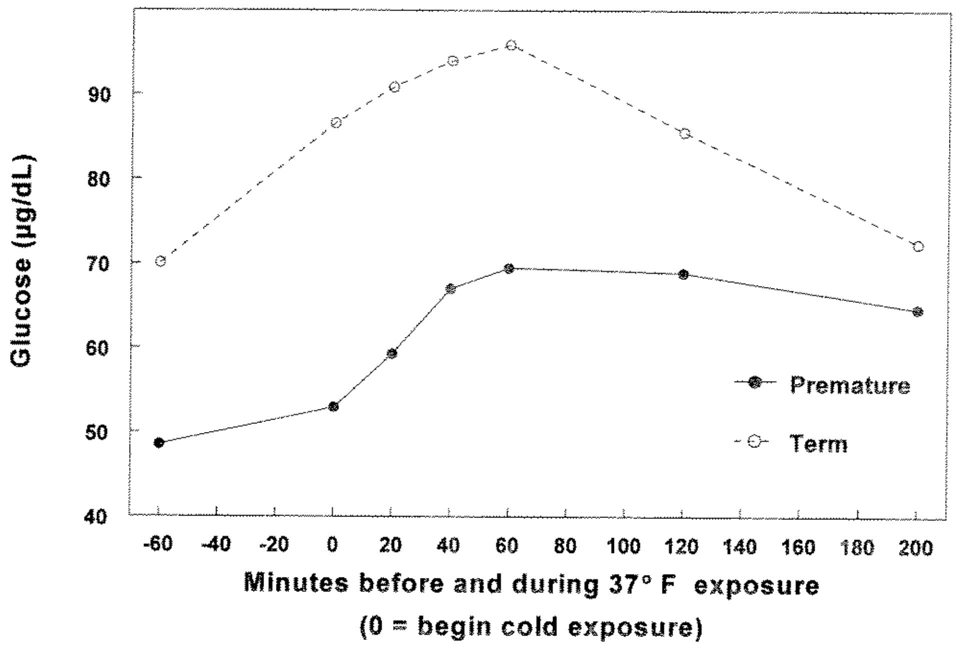


Figure 4. Plasma glucose concentrations of newborn mature and premature calves exposed to 37° F for 200 minutes and born to cows receiving 1.5% (LF) or 3.4% (HF) dietary fat 28 days before calving.

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

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

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

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

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

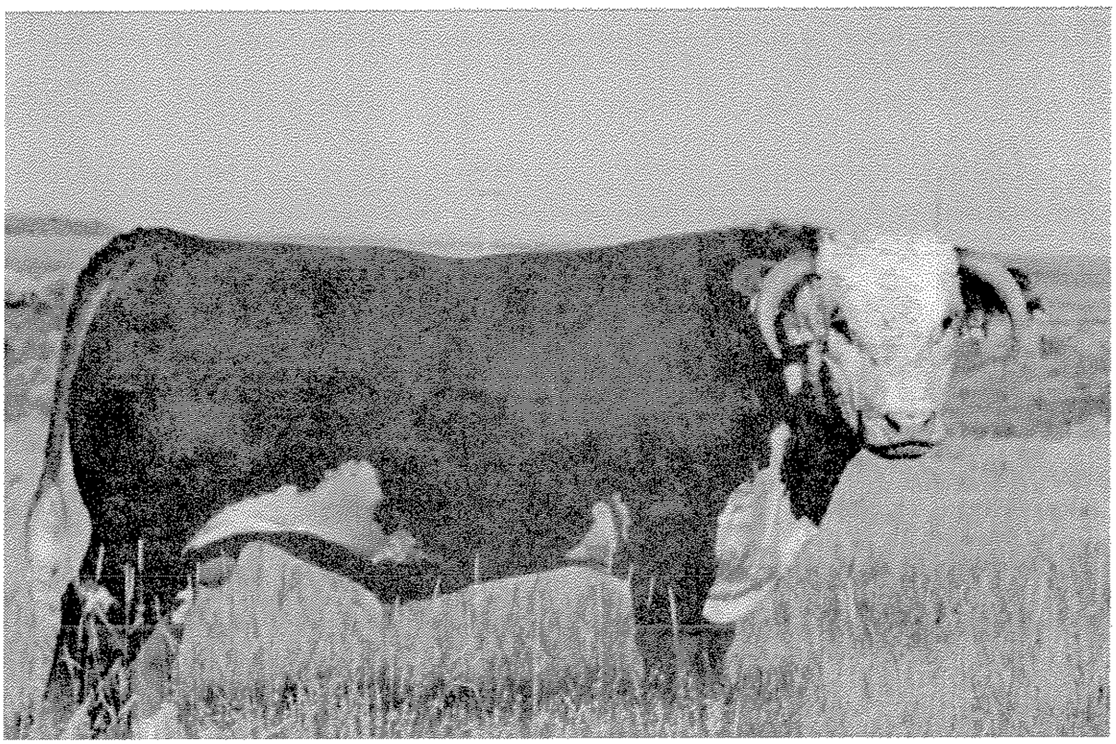
Feeding fat for the last 28 days of gestation was not enough to alter heat production of newborn term or premature calves exposed to 37 °F. Premature calves had lower blood glucose concentrations than term calves (Figure 3) and premature calves were also cold intolerant (Figure 4).

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

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

E. Genetic Improvement

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



Line 1 Bull

Selecting Beef Cattle to Genetically Increase Profit

M.D. MacNeil and S. Newman

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

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

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

Step 1 is to determine the economically important traits and the relative value of each of them. This requires a sound and complete description of a beef production system. A computer simulation model is a useful tool for this purpose. With the model, changes in profit that occur when changing one trait by itself holding all other traits constant can be estimated. These changes in profit are referred to as relative economic values for the traits. At this point whether or not the trait can be measured is not a consideration. The only concern is with finding the traits that are important and computing their contribution to profit from the production system. For example, about ⅔ the cost of cow-calf production stems from feed required by the cow-herd. Yet feed intake is very costly and difficult to measure on each cow. Even so feed intake can be one of the important traits to consider in making selection decisions.

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

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

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

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

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

Hence, Profit = 20NR + 1CM.

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

In *step 2*, three traits, birth weight (BW), yearling weight (YW), and scrotal circumference (SC), may be useful as selection criteria. All three are easy to measure early in the life of bull calves. Birth weight has a moderate to high genetic correlation (r_g) with CM, especially the weight component. Birth weight also has a low to moderate r_g with net reproduction, arising mainly through the association of birth weight with calving difficulty. In this example, YW is not related to NR. This is due to BW being held constant in determining the relative economic value of YW. However, YW has a high r_g with the weight component of carcass merit. Finally, SC has a moderate to high r_g with NR as discussed previously. It also has a low to moderate r_g with CM arising from the r_g of carcass quality and early maturity.

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

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

Then consider 5 candidates for selection with these records:

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

Their evaluations for profit potential are:

Bull no.	Evaluation	Rank
93502	-0.034(90) + 0.031(1012) + 0.193(34) = 35.1	5
95552	-0.034(99) + 0.031(1087) + 0.193(36) = 37.3	2
93452	-0.034(70) + 0.031(1021) + 0.193(33) = 35.6	4
93469	-0.034(97) + 0.031(1069) + 0.193(36) = 36.8	3
93507	-0.034(88) + 0.031(1208) + 0.193(38) = 41.8	1

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

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

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

their evaluations for potential contributions to profitability are:

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

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

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

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

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

MacNeil, M.D., S. Newman, R.M. Enns, and J. Stewart-Smith. 1992. Temporal variation in relative economic values for specialized sire and dam lines in Canada. J. Anim. Sci. 70(Suppl. 1):140.

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

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

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

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

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

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

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

MacNeil, M.D. 1994. On what criteria to base future genetic improvement? Western Stock Grower, p 3-5.

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

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

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

"Marker Assisted Selection" Made Easy

M.D. Grosz and M.D. MacNeil

What are cells, chromosomes, genes, and alleles?

The bodies of all plants and animals are made up of millions of **cells**. A cell is a microscopic "bag" which is designed to perform a specific function. Different types of cells exist such as skin cells, nerve cells, muscle cells, and blood cells. Each cell contains the structures necessary for that cell to carry on its function (Figure 1). Those structures include a cell membrane (which encloses the cell and keeps it together), mitochondria (which provide energy for the cell to perform its function),

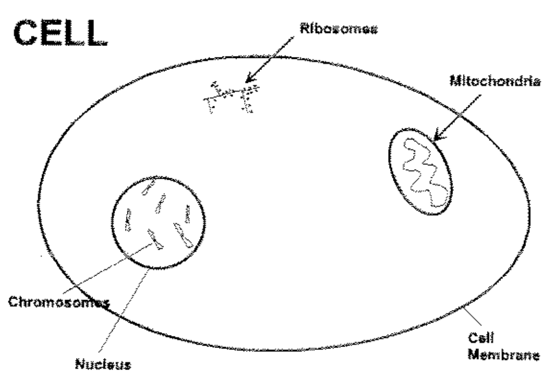


Figure 1. A Cell, including Nucleus, Cell Membrane, Mitochondria, Ribosomes, & Chromosomes.

ribosomes (which use genetic information to produce proteins for that cell, or other cells, to use), and a **nucleus** (which has been referred to as the "brain" of the cell). It is within the nucleus of the cell that the **chromosomes** reside.

Chromosomes come in pairs (one having been received from each parent), and consist of long stretches of a chemical called deoxyribonucleic acid (DNA). The shape of the DNA is called a double helix, and the "rungs" on the ladder are called "base pairs" (Figure 2). Each base pair is actually one of four possible molecules (Guanine, Adenine, Thymine, or Cytosine; G, A, T, or C).

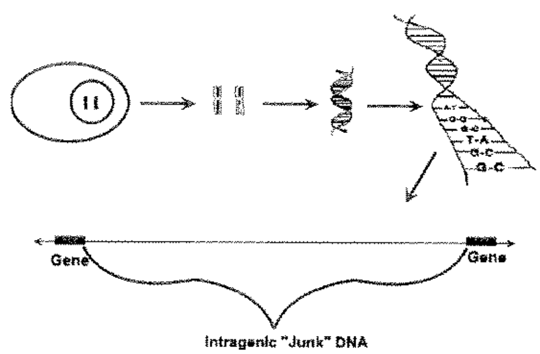


Figure 2. Structures of DNA. Intragenic DNA (DNA whose function is, as of yet, unknown) makes up about 99% of all DNA.

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

A typical gene may consist of about 5,000 base pairs. It has been estimated that there are approximately 3 billion base pairs, encoding more than 100,000 genes, in the bovine genome (**genome** refers to the entire complement of chromosomes). Cattle cells contain 30 pairs of chromosomes and each chromosome has about 150,000,000 base pairs, encoding about 5000 genes. Genes make up about 1% of all DNA. The remainder of the DNA (99%) has no known function, yet it remains for some reason not yet understood (therefore it is called "junk DNA").

Any sequence differences in a gene (chemical changes in the DNA molecule) may result in the production of a different form of a protein. This variant form of a gene is called an **"allele"** (Figure 3). The function of an allele will be the same, but, because of the sequence difference, it may not be able to perform that function properly. Alleles can be compared to automobiles, all perform basically the same function, but some perform that function better than others.

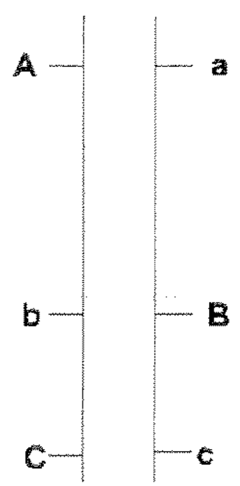


Figure 3. A hypothetical pair of chromosomes with 3 genes ("A," "B," and "C") and two alleles for each gene (uppercase and lowercase).

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; and **"complex"** traits, which are determined by more than one gene. Complex traits are almost always also affected by the environment. An example of a simple trait is whether a cow is horned or polled. An example of a complex trait would be how much each of us weighs. While we would like to blame our weight problems on genetics, some of it also has to do with how much we eat. Complex traits are also known as "quantitative" traits, since the phenotype can 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 cells that make up body tissues are called "somatic cells." As our bodies grow, a mechanism is needed to form new cells and replace cells that die or that are lost due to injury. This process is known as **"mitosis"** (Figure 4). During mitosis, the chromosome pairs line up in the cell and duplicate. After duplication is complete, one copy of each chromosome pair is distributed to each daughter cell, producing two identical cells.

During the production of germ cells (sperm and egg cells), a different process is required. Each germ cell must contain only one of each chromosome (not a pair), so that after fertilization, the embryo will again contain a pair of each chromosome. After fertilization (the union of the sperm

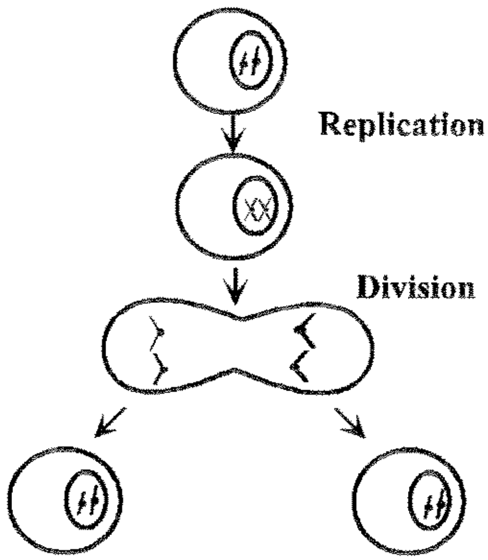


Figure 4. Mitosis. Each of the two daughter cells is an exact copy of the original cell.

and egg), the embryo will then contain a pair of each chromosome (which is why each animal receives half of their genetic information from each parent). The type of cell division used to create germ cells is called "**meiosis**" (Figure 5). Meiosis begins much like mitosis, with the chromosomes lining up in the cell and duplicating. At this point, a very important process takes place, called **recombination**. During recombination, portions of chromosomes are exchanged with the other chromosome of the pair. Following recombination, there are two rounds of division, leaving 4 cells, each containing one chromosome (not a pair).

Recombination is an important process for two reasons. First, recombination increases the amount of variation in a population, since new combinations of genes are constantly being produced. Second, recombination allows a system to measure the distance between two genes. This system uses the frequency of recombination between two genes as the distance (for example, if there is recombination between two genes 5% of the time, the two genes are said to be 5 centimorgans apart). If two genes are very close together, there is very little recombination between them, and they are said to be "**linked.**"

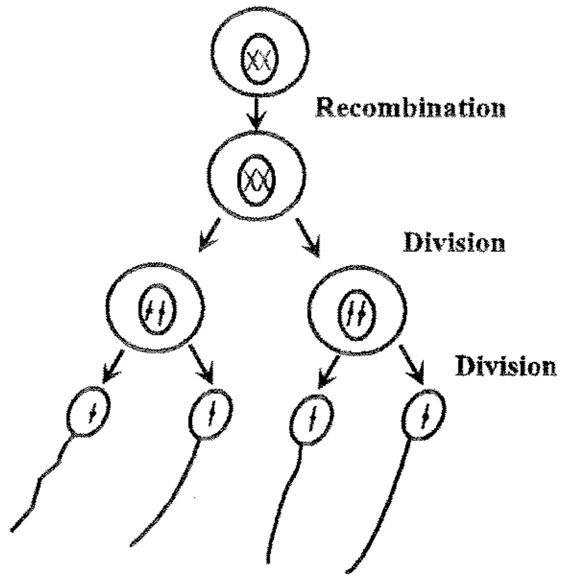


Figure 5. Meiosis and Recombination. Each of the four daughter cells (eggs or sperm) contains only one of each chromosome, which may have undergone recombination.

What is a marker?

In order to study recombination, we must be able to tell the difference between different alleles. If there are different alleles for a particular locus (address on a chromosome), that locus is called "**polymorphic**" (literally "many forms"). If there is no variation, and the sequence of a locus is identical in all animals, that locus is called "**monomorphic**" (literally "one form"). It is polymorphism that makes each individual unique. An example of polymorphism can be seen by looking at a group of people. One (of the more than 100,000 genes in the nucleus of each cell) controls whether or not ones earlobes are attached to the side of our head, or whether they hang down. By understanding that there are 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 a lot of polymorphism. The identification of a marker allows us to look at the frequency of recombination between that marker and other genes which may or may not be "linked" to the marker. Markers become more powerful as linkage relationships between many markers are identified. Much in the same way as a child "connects the dots" to create a picture, linkage relationships between markers are identified, and groups of linked markers are placed on linkage maps.

A common analogy has been drawn between genetic markers on a chromosome and mile markers on a highway. If one asks "where is mile marker 38?", the only answer is "in between mile markers 37 and 39." Similarly, the only information that can be obtained from a marker is "which loci are nearby?". By developing large numbers of markers, we can begin linking markers together to create linkage groups, or linear groups of markers, separated by known genetic distances.

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, we have developed new kinds of markers that allow us to look directly at the DNA. The standard criteria used in the assessment of a marker are: 1) the marker must represent a single locus, 2) there must be a large amount of polymorphism, 3) the marker must be scored objectively, 4) scoring the marker must be resource efficient, and 5) if possible, the marker should be at a known chromosomal location.

Genotypic markers can exist either within a gene, or in the DNA in between genes. Since we know that there is more polymorphism in the DNA between genes, markers located in between genes (in the "junk DNA") generally make better markers.

What is "Gene mapping?"

We know 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 to the offspring. We can use markers to help us 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 tell us which markers are closest to the gene which controls the trait. However, if the gene affects a complex trait, there is too much "noise" (affects of other genes and the environment), and it is not possible to say which QTL allele the offspring got by gross observation. (For example, approximately 40% of the total variation in weaning weight is controlled by "genetics." There may be 10 genes which affect weaning weight, each with an equal impact of 10% of the genetic variation. Because the variation from the other 9 genes is affecting 90% of the genetic variation, we can't reliably score animals on the basis of one of the genes). Nevertheless, we can find statistical associations between inherited markers and averages for a complex trait if we survey enough animals.

A simplified example of gene mapping would be as follows. A rancher has a calf crop in which half of the calves are green and half are red. The rancher notices that the green calves, on average, tend to be heavier than the red calves at weaning. The rancher has used a phenotypic marker (coat color) to identify a genetic region in which a gene affecting the complex trait of weaning weight exists. The reason why green calves tended to be heavier is not because there is anything special about the color of the coat, but because the two genes (coat color and weaning weight) are very close to each other on a chromosome. Very little recombination occurred between the two genes. Therefore, calves that were green also tended to be slightly heavier.

What is "Marker Assisted Selection"?

Marker assisted selection is 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. In the example of the green and red calves, the rancher would obviously breed the green calves, since the allele for green coat color was linked to a QTL for higher weaning weight. The same principle holds for genotypic markers. Once markers are identified which are linked to genes which affect traits of economic interest, these markers can be used to determine which animals should be bred to produce the next generation.

There are three major advantages to using marker assisted selection over traditional methods. First, animals can be objectively typed for markers. There is no "judgement call" or other subjective measure; the test is as simple and more reliable than blood typing. Second, typing can be done at birth (or sooner); eliminating the problem of breeding an animal after it has been slaughtered. Third, 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%.

Conclusion

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

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

Use of Markers at Fort Keogh

A search for important genetic markers associated with production traits in the Line 1 Hereford population is underway as part of the current research program at Fort Keogh Livestock and Range Research Laboratory. This research has brought major changes to the traditional selection experiments done at Fort Keogh. In order to identify those alleles coming from Line 1 that make a significant contribution to the level of a production trait requires that crosses be made between Line 1 and a population which does not possess the candidate allele. We chose to make these crosses with our CGC composite (½ Red Angus, ¼ Charolais, and ¼ Tarentaise) population. Preliminary results indicate there is enough genetic difference between these two populations to result in a powerful experiment.

The basic design of this experiment requires two generations of breeding as shown in Figure 6. Stereotypically, a Line 1 bull having genotype AA and a CGC cow having genotype aa were crossed to produce a bull with genotype Aa. Thus, the "A" allele came from Line 1 and the "a" allele came from CGC. This crossbred bull is being bred back to both Line 1 and CGC cows. Calves resulting from mating the crossbred bull with Line 1 cows will have genotypes AA and Aa, while calves from matings of the crossbred bull with CGC cows will have genotypes Aa and aa. Relative performance of the groups of calves with these different genotypes will then be related to the "A" and "a" alleles and to the populations from which they came. In the end, the relative value of both alleles as they affect the various production traits is determined. If one marker allele is greatly favored over the other, these results can serve as the basis for marker assisted selection.

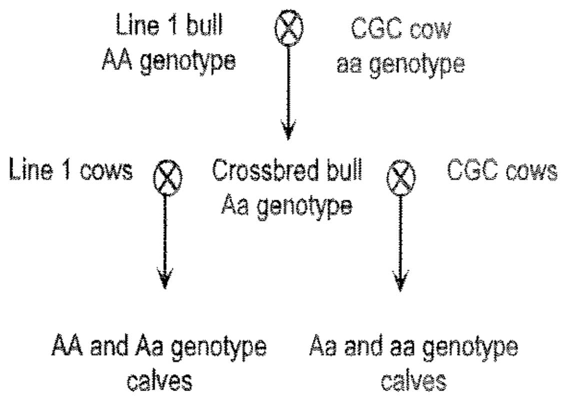


Figure 6. Matings to produce calves needed to identify genetic markers. ⊗ designates "bred to" and arrows point toward resulting offspring.

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

Efficient use of these results will depend on refinements to TPR that incorporate marker information in the genetic predictions and on broadening the array of traits for which genetic predictions are made available. However, it is likely that there are alleles at other loci besides those presently being examined which are also important. In addition, there are probably a variety of alleles which are not present in the particular groups of cattle in this study. Future research efforts should help identify more of these important alleles and develop ways to put them to use.

A brief history of marker assisted selection

1950s:	Research on marker assisted selection begins using blood types as markers. These studies are limited by the number of markers, and provide inconsistent results.
1989:	The discovery of "microsatellites" allows for the production of large numbers of markers. The focus of research is humans and mice.
1992	USDA begins large scale production of bovine microsatellites.
1993	Publication of more than 2000 mapped mouse microsatellites.
1994	Publication of more than 300 mapped bovine microsatellites.
1994	A study using a cross between wild boar and commercial Large White pigs found QTLs affecting growth rates, the amount of fat in the abdominal cavity, subcutaneous fat, and length of the small intestine.
1995	A study in dairy cattle showed that even in highly selected lines there is still significant polymorphism in QTLs (indicating the potential for increased improvement in dairy cattle).
1997	?????????????????????

Effects of Different Statistical Models on Prediction of Expected Progeny Differences

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

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

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

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

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

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

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

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

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

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

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

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

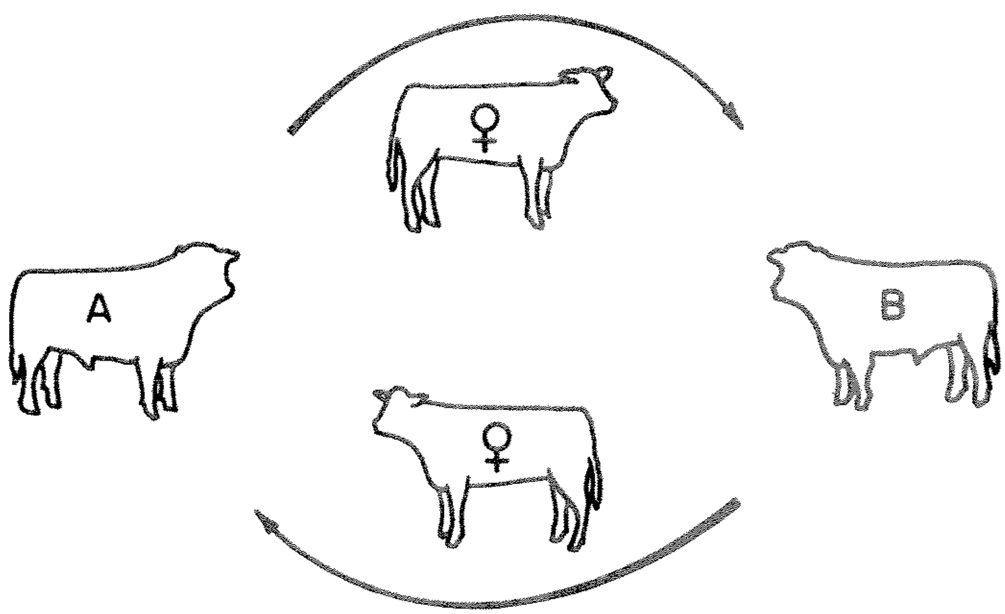
Gengler, N., L.D. VanVleck, M.D. MacNeil, I. Misztal, and F.A. Pariacote. 1997. Influence of dominance relationships on the estimation of dominance variance with sire-dam subclass effects. J. Animal Science (submitted).

F. Mating Systems

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

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

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



Heterosis and Inbreeding Depression

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

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

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

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

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

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

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

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

Genetic Conservation of Line 1 Hereford Germ Plasm

M.D. MacNeil and R.B. Staigmiller

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

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

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

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

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

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

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

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

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

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

G. Producing Lean Beef

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Effects of Hypermuscularity on Beef Production

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

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

One strategy to reduce fat production is to use muscular breeds of cattle. The increased muscling could be as extreme as in Piedmontese or Belgian Blue or more moderate as in other European breeds such as Limousin, Charolais, or Maine-Anjou. In the extreme, this trait is called hypermuscularity or double-muscling. Calves sired by these breeds may have more desirable carcass composition compared with calves sired by breeds with less extreme muscularity. Using more muscular breeds has potential for immediately improving composition without using drugs or implants.

Use of hypermuscularity or double-muscling in beef production systems is hampered because its inheritance is not fully understood. Without this knowledge, it is difficult to design breeding systems. Also unknown are the effects of hypermuscularity on other important production traits such as reproduction. The goals of this research are to better understand genetic control of hypermuscularity and its associations with other economically important traits.

Procedures: Crossbred cows and heifers that did not have extreme muscularity were bred by AI to bulls from breeds with differing genetic potentials for muscularity. Piedmontese (P) bulls represented hypermuscularity (HM) genotypes, Limousin (L) bulls represented genotypes with more moderate muscularity (MM), and Hereford (H) bulls represented normal muscularity (NM) genotypes. About 300 F1 progeny were produced from each breed of sire over two years. Within each breed, 20 to 25 different bulls were used to insure a broad sampling of each genotype.

Effects of degree of muscularity on slaughter and carcass traits are determined using the F1 male calves. The F1 females have been bred with bulls of the same cross to produce F2 progeny for three years. Reproductive performance by these females contributes to determining effects of muscularity on reproductive traits. In the F2 progeny, segregation of genes for muscling will yield data to understand their inheritance. Degree of muscling for individual animals is being assessed by a com bination of visual scores, ultrasound measurements of muscles, microscopic (histological) measurements of muscle biopsies, and carcass data.

Findings: Collection of data at calving, weaning, and slaughter data of the F1 calves has been completed. Age at puberty has also been determined for all F1 heifers. Degree of muscularity had little effect on calving or weaning data (Table 1) except that calving difficulty increased with increased muscularity. Age at puberty was markedly different among the three genotypes (Table 1). The MM genotype was oldest and the HM genotype was youngest at puberty.

The carcass data (Table 2) were consistently related to muscularity. As muscularity increased, fat depth and marbling score decreased and ribeye area, dressing %, and primal cuts increased. Tenderness was also affected by genotype. Steaks from HM were most tender and steaks from MM were least tender. Gain and efficiency differed among the genotypes (Table 2) with MM growing fastest and most efficiently, followed by NM, and then HM.

Use of sires with increased muscularity can increase production of lean beef while maintaining sufficient levels of traits associated with consumer preferences. The HM-sired cattle produced carcasses with up to 25% more lean and with less in fat than NM-sired cattle. Because the increased muscularity arises from exaggerated development of muscle fibers, the connective tissue component of the meat is altered and it is more tender. If HM genotypes were used to sire slaughter progeny, consumers could obtain beef that is highly palatable and be less concerned about fat intake.

Future Directions: Evaluation of reproductive performance by the F1 females is continuing as is production of F2 progeny for genetic evaluations.

Table 1. Effects of genotype on calving, weaning, and puberty traits of F1 calves.

Genotype (Sire Breed)	Gestation length, days	Birth weight, lb	% calving difficulty	Weaning weight, lb	Heifer age at puberty, days
NM (H)	283	84.7	14.9	453	378
MM (L)	287	89.3	20.2	456	399
HM (P)	288	88.7	24.6	452	356

Table 2. Effects of genotype on carcass traits of F1 calves.

Genotype (Sire Breed)	Live wt (lb)	Carcass wt (lb)	Ribeye area (in^2)	Fat depth (in)	Marbl ing score	Tender-ness test (lb)	% Primal cuts	Gain (lb/day)	Effic-iency (oz/lb)
NM (H)	1174	684	12.5	.32	11.7	7.8	53	2.8	3.3
MM (L)	1187	700	13.3	.25	10.3	8.1	54	2.9	3.6
HM (P)	1151	698	14.6	.16	9.4	7.3	55	2.6	3.2

Relevant Publications: Grings, E.E., R.E. Short, M.D. MacNeil, M.A. Lammoglia, R.B. Staigmiller, and R.A. Bellows. 1997. Postweaning production of F1 males from Hereford, Limousin, or Piedmontese sires. J. Animal Sci. (In preparation).

Comparison of Ultrasound Systems to Predict Marbling in Beef Cattle

M. D. MacNeil, W. O. Herring, L. A. Kriese, K.K. Bertrand, and J. Crouch

Problem: Marbling is an important determinant of carcass value. Using ultrasound to predict marbling in live animals may improve feed-yard management and accelerate genetic improvement. Today, there are several commercially available ultrasound systems that claim to predict marbling. Therefore, the Beef Improvement Federation Live Animal and Carcass Evaluation Committee asked that a series of studies be conducted to evaluate these systems. This study contributes to that goal.

Procedures: Cattle used in this study were Line 1 Hereford (n=48) and CGC composite (n=32) steers. Intact bulls were fed from weaning to about one year of age. The diets were based on corn silage with some added grain, primarily barley, and 10% chopped hay. At one year of age the bulls used were identified as culls due to either low performance or excessive birth weight. They were castrated using the Callicrate system. These steers then grazed native range at Miles City until August 21 when they were returned to the feedlot for finishing. Coming off pasture their average weight was 966 pounds. The finishing ration consisted of 80% well eared corn silage, 10% corn grain, and 10% barley.

Four commercially available ultrasound systems were represented in this study. These systems all estimated marbling by applying image analysis procedures to a region of interest within the rib-eye muscle. To allow the best possible representation of each system, each company was allowed to select and send two experienced technicians. The systems[1] represented were: Animal Ultrasound Services Inc., Ithaca, NY; CPEC, Oakley, KS; Critical Vision Inc., Atlanta, GA; and Classic Ultrasound Equipment, Tequesta, FL. The CPEC systems predicted marbling score directly. The other systems predicted percent fat within the muscle which was converted to marbling score. These evaluations reflect the state of technological development as of October, 1996. Later changes to these systems may alter their performance.

Animals were scanned over 3 days. Cattle were sent to slaughter in four groups of 20 head each, beginning the day after scanning and every 7 days thereafter. Marbling was determined 36 to 48 hours after slaughter by an experienced grader. After grading a slice of the rib-eye muscle was taken to determine percent fat within it. The correlation between marbling score and percent fat was 0.74.

Several statistics were used to evaluate the proficiency of each system. Rank correlations assist in determining similarity of the ranking of two variables. In this case, they were marbling predicted using ultrasound and marbling scored by the grader. Accuracy assists in determining the similarity of predicted marbling and its direct observation. Bias indicates the magnitude and direction error.

Findings: The carcass data recorded in the cooler are presented in Table 1. These cattle were fed for less than 90 days and castrated at a year of age. Thus, the fat and muscle traits may be more similar to those of bulls than of steers.

Table 1. Description of live and carcass data

Trait	Minimum	Mean	Maximum
Live wt., lbs.	1014	1166	1333
Carc. wt., lbs.	565	656	752
Fat depth, in.	0.05	0.24	0.60
Ribeye, in.[2]	9.3	12.1	15.9
Marbling[a]	3.4	4.5	6.1

[a] 3=traces, 4=slight, 5=small, 6=modest

Presented in Table 2 are descriptive statistics relating ultrasonic predictions of marbling, by system to the observations. The CPEC and Critical Vision systems had the higher correlations with measured marbling and greater accuracy and less bias in its prediction than did Animal Ultrasound Services and Classic Ultrasound Equipment systems.

Table 2.

System[a]	Correlation	Accuracy	Bias
CPEC	0.54	0.57	-0.09
CVIS	0.47	0.64	-0.13
AUS	0.03	2.12	0.95
PIE	-0.04	1.75	-1.06

[a] CVIS=Critical Vision; AUS=Animal Ultrasound Services and PIE=Classic Ultrasound Equipment.

Results from these data agree with earlier studies evaluating these technologies. It is feasible to use ultrasound for predicting marbling. However, not all commercially available sys tems are equivalent. Thus, before using ultrasonic predictions of marbling in decision making the utility of the particular system should be established.

Future Directions: Collaborative studies in service to the cattle industry are central to the mission of Fort Keogh Livestock and Range Research Laboratory. As opportunities to provide this service arise they will be pursued with vigor.

Relevent Publications: Herring, W.O., M.D. MacNeil, L.A. Krise, J.K. Bertrand, and J. Crouch. 1997. Comparison of four real-time ultrasound systems that predict intramuscular fat in beef cattle. Proc. Beef Improvement Federation, Dickenson, ND. (in press).

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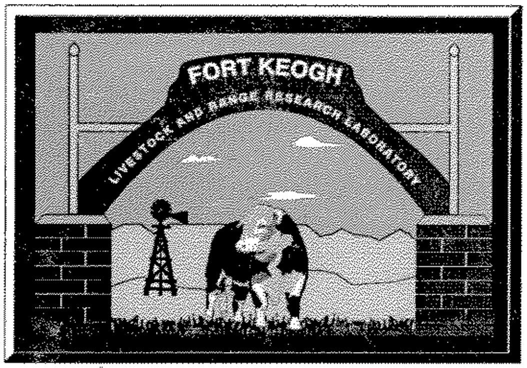

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