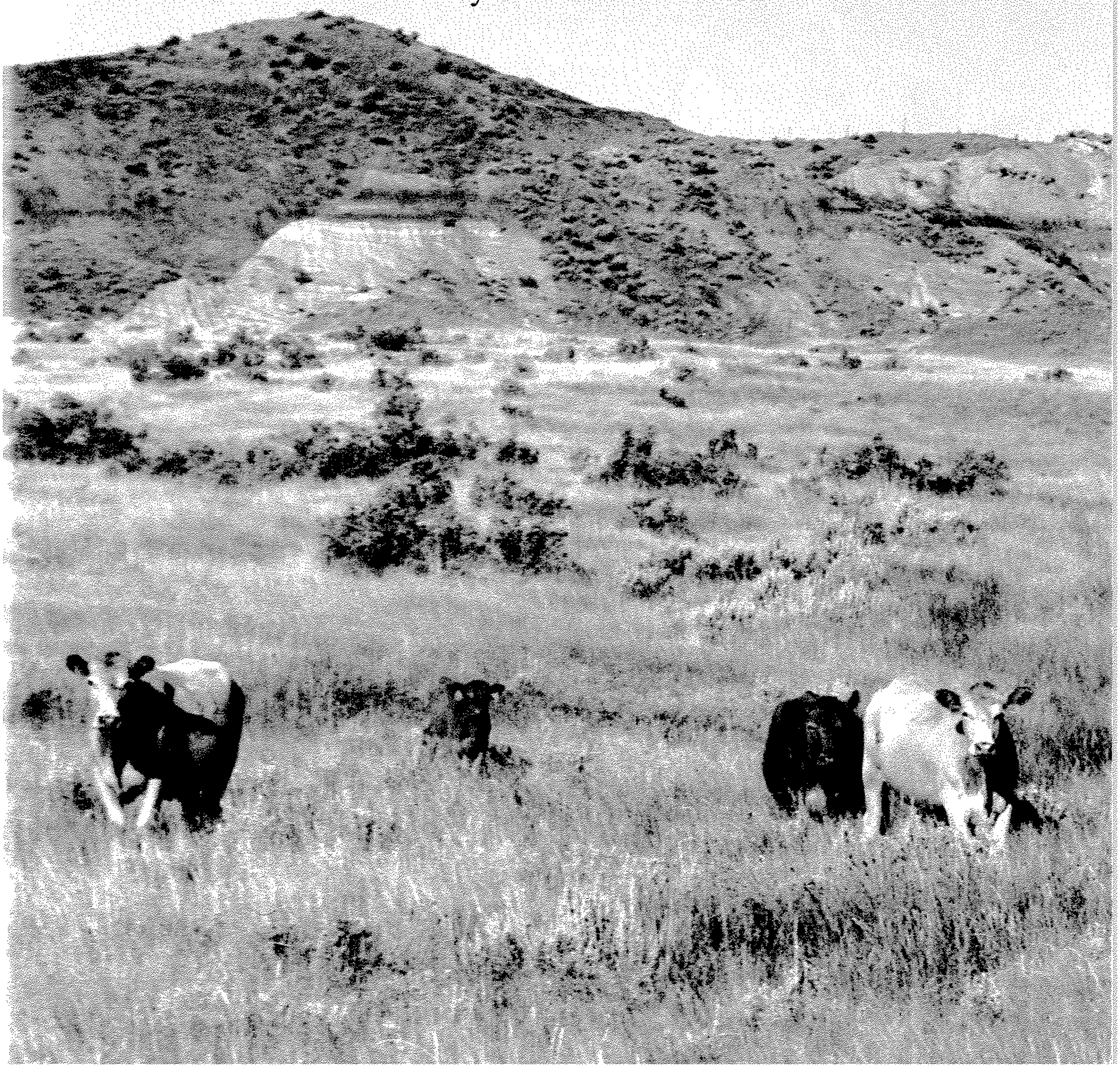
Research for Rangeland Based Beef Production

United States Department of Agriculture
Agriculture Research Service

Fort Keogh Livestock and Range
Research Laboratory
in cooperation with
Montana State University



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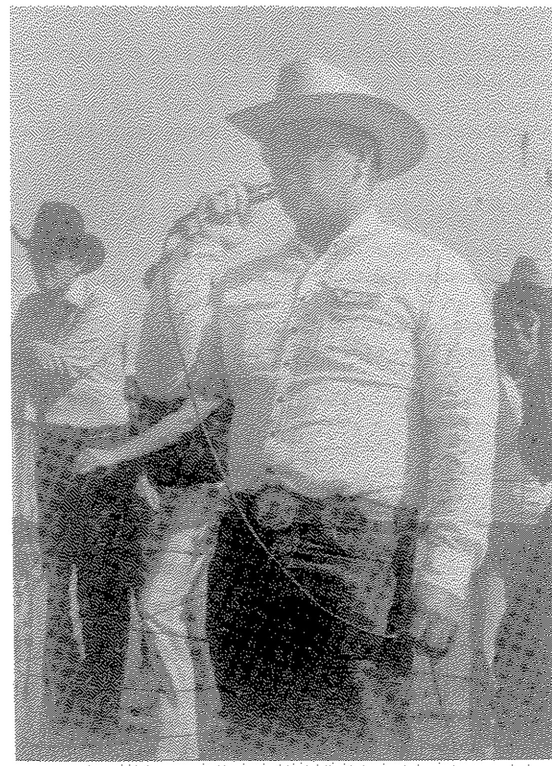
PRODUCER RECOGNITION AWARD

James Frank Sparks

Plevna, Montana

Biography



James Frank Sparks was born August 21, 1927 to pioneer ranchers on their homestead near Plevna, Montana. He attended the local Lame Jones Community Elementary School, completing the 8th grade with perfect attendance. Frank graduated from the Graham School of Livestock Management and AI in 1956 and attended the Savory School for Holistic Management in 1986. He is an avid reader and keeps up with changes in the industry by reading articles from numerous periodicals.

He purchased a neighboring homestead in 1947 and additional land later. Frank married Goldie E. Collie on September 8, 1948. The family has three sons: James of Glendive, Thomas of Plevna, and Donald of Bowman, North Dakota.

As a lifelong Hereford breeder, he has maintained Line 1 and Line 6 cattle and an imported Torrington line. He experimented with inbreeding and had coefficients of inbreeding as high as 50% in individual animals. He has purchased both Line 1 and Line 6 cows and bulls. The Torrington Line was added in 1960 and a bull imported from England in 1967. A complete performance data record has been maintained on all his cattle since 1956. As a believer in survival of the fittest, he practices what he preaches through a rigid culling program. He has worked diligently to relate barometric pressure and lunar cycles to bovine endocrine cycles and growth rates and has utilized this information to select animals in his herds. For many years he also raised Montana No. 1 hogs and actively conducted inbreeding studies with the hogs.

In 1961, Frank was the recipient of the Ford Motor Company, Beef Efficiency Award and a grant of $2,500, to be donated to the institution of his choice. This award resulted from his providing carcass data derived from calves sired by one of his Line 1 bulls. He graciously donated the award to Fort Keogh Experiment Station to purchase a Sonar backfat measuring machine. He was recipient of the first Montana State Rural Area Development Producer Award in 1984.

Frank is a charter member and past president of The Montana Beef Performance Association, and member of the American Hereford Association, Montana Stockgrowers Association, Montana Farm Bureau, and Society for Range Management. He is also past president of the Northern Great Plains Section Society for Range Management. He has served on the Montana Livestock Sanitary Board, Bureau of Land Management Advisory Council, Montana Rural Area Development Range Committee, County Farm and Home Administration Committee, and local school boards.

Frank has contributed greatly to the conservation of range resources in eastern Montana. He modified and demonstrated the effectiveness of the contour furrower for enhancement of water retention on rangelands thus reducing the degree of decline in forage production often observed during periods of drought. He began working toward modification of existing machines in 1964 and completed his model by 1965. This machine is currently being used in four states to improve utilization of precipitation and increase forage production on rangelands. Frank continually shares his ideas and practices with interested groups by providing tours on his ranch and presenting talks and slide shows at field days around the state.

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PRODUCER RECOGNITION AWARD

Dale H. Davis

Belgrade, Montana

Biography

Dale H. Davis was born to homesteader parents August 26, 1925, at Belfield, North Dakota. In 1936 following 4 years of extreme drought, the family moved to a small ranch in Bridger Canyon east of Bozeman, Montana. Their household goods, horses, cows and sheep were moved in an "emigrant" car and two stock cars on the Northern Pacific Railroad.

Dale brought two registered Angus heifers for his F.F.A. project in 1939, but four years later he enlisted in the Navy. Dale and Betty Jo Cole were married on December 29, 1946, while both attended Montana State College. In 1956, they leased a small ranch on Reese Creek northeast of Belgrade, Montana, and Dale again pursued his dream of having registered Angus by buying twelve heifers with calves from John Heath of Clyde Park, Montana.

In 1956, Dale attended a Beef Production School at MSC where he learned of heritability estimates for some economically important traits from research at the U.S. Range Station at Miles City. Obvious new tools were available for beef cattle improvement. Dale was involved in the Montana Beef Performance Association and helped set a new direction for beef cattle selection and breeding. Dale served two 3-year terms as a director (1960-62; 1969-1971) and two 1-year terms as President (1963; 1972). He repeated the sequence again in 1973.

As performance testing based on accurate within herd comparison grew, so did Dale & Betty Davis' Rollin' Rock Angus herd. They also participated in both of Montana's Central tests and had high gainers and sellers at both stations. In 1970, they held their first annual production sale with bulls and heifers going to seven states. By 1972, they had bought and paid for additional land and had a herd of 175 registered Angus cows.

Betty passed away on November 28, 1972. With support from his daughter, Patricia, and his two sons, Bill and Tom, and other family and friends, the ranch operation continued to function. Bill and family returned to the ranch in 1973.

Dale and Carol Bishop were married and moved to the town of Belgrade. Dale and Carol remained active in the Angus operation and he was elected to the Board of Directors of the American Angus Association from 1973-1979. He was active in breed improvement and Angus Herd Improvement Records program formation and played a key role in charting the course for performance programs, EPD's and sire summaries presently in use.

In 1977, Dale served in the Montana legislature as State Representative. Due to health reasons, he declined to run for a second term. Dale and Carol sold their interest in Rollin' Rock Inc. to his son, Bill, and family in the fall. Later that year, they commenced to build a select linebred herd of performance Angus. They purchased several cows that were descendants of RR Rito 707 the foundation sire for Pioneer Hibred International that was owned jointly with ABS. Dale and Carol also purchased some of the older Rollin' Rock cows.

Today the new herd called PAPA (Practical and Predictable Angus) has grown to over 100. Their daughter, Patricia, and a neighbor run portions on shares. The PAPA herd is one of four herds that make up the group called The Performance Breeders. PAPA bulls make a substantial contribution to the successful "Annual Performance Breeders Bull Sale" held the past 3 years at Belgrade.

Dale serves on the MSGA Liaison committee at Miles City and the MSU Animal and Range Science Advisory Committee. He is an immediate past member of the MAES Advisory Council. He is a past President of the Montana Angus Association and is presently serving on the Board of Directors again for that organization as well as the South Montana Angus Association.

A DECADE OF RANGE BEEF CATTLE NUTRITION RESEARCH

D. C. Adams[1]

Introduction

Range animal nutrition is a key to interfacing plant and animal research. Range nutrition has been an important area of research at USDA-ARS Fort Keogh LARRL since the mid-1970's. A review, summary, and literature citations of this research follows.

The goal of the range nutrition research has been to reduce limitations of a cyclic range forage resource on beef production and to improve efficiency of production. This research has focused on 1) development of methodology to accomplish research objectives, 2) development of a data base and management strategies that could be utilized in today's production systems and 3) study of biological mechanisms.

Methods and Results

An automated range animal data collection system was developed to collect daily weights and water intake of grazing cattle without human intervention (Adams et al. 1987b). Use of this system has provided data to more precisely determine relationships between forage characteristics, environment and animal gains (Currie et al. 1989; Adams et al. unpublished). Currie et al. (1989) developed growth curves for yearlings on summer range from daily weights. Daily gains by yearlings were small to negative by early August, and gains remained small into September even when August rains occurred. Interestingly, weights taken at 28-day intervals in this study showed cattle to be gaining weight in August at a rate similar to that in June or July. A data set of daily weight and water consumption of cattle receiving various winter supplement treatments is presently being prepared for publication.

Determination of forage intake by grazing cattle has been a significant obstacle to research. Intake has generally been estimated by measuring fecal output and dividing it by forage indigestibility. Two methods to more readily and precisely determine fecal output (Cochran et al. 1987a; Adams et al. 1990a) and 5 methods for more precisely determining forage indigestibility (Cochran et al. 1986) were evaluated and/or developed for range nutrition research. Use of these methods has greatly expanded grazing animal research at Miles City, and data that was once thought impractical to collect is now being collected.

A method for surgical establishment of esophageal fistula in suckling calves was developed (Adams et al. 1990b). Diets of suckling calves were compared to those of mature steers (Adams et al. 1990). Interestingly, in June, July, and September, diets of the calf were about 30 to 38% greater in crude protein than mature steers (Table 1). Diet collection and fecal collection of suckling calves has greatly expanded the research at Miles City into evaluation of different biological types of cattle and quantification of nutrient inputs required by a cow/calf pair. With daily estimates of gain by the calf and nutrient intake by the cow and calf, efficiency of production is now being determined for cattle grazing on rangeland.

Collection of diet samples can be very time consuming. To help alleviate this problem, we developed a simple procedure for attachment of esophageal bags to cattle (Kartchner and Adams 1983). This simple procedure reduced the time to attach a collection bag by about ⅔'s, eliminated several straps, and facilitated changing bags in pen or pasture rather than chutes. We found this procedure particularly helpful during collections made in harsh winter weather or where cattle handling facilities are some distance from the site of collection.

Table 1. Crude protein[a] in the diets of suckling calves and mature steers at various dates.

	Date		
	June 13	July 26	September 20
Mature Steer	9.1	6.1	4.1
Suckling Calf	13.1	9.7	6.4

[a] Expressed as a percentage of organic matter.

Mathematical models and sampling procedures were studied for estimating rate of particulate passage through the gastrointestinal tract of cattle (Cochran et al. 1986b; Cochran et al. 1987a). This methodology has been used in other studies to help understand relationships between forage maturity and supplementation on forage intake and beef production. Passage rate of forage through the gastrointestinal tract declines as forages mature (Ward et al. 1990a; Ward et al. 1990b). If methods can be found (i.e. appropriate supplementation) to increase passage rate of forage, intake of forage might be increased to help cattle more readily meet their nutrient requirements when grazing poor quality ranges.

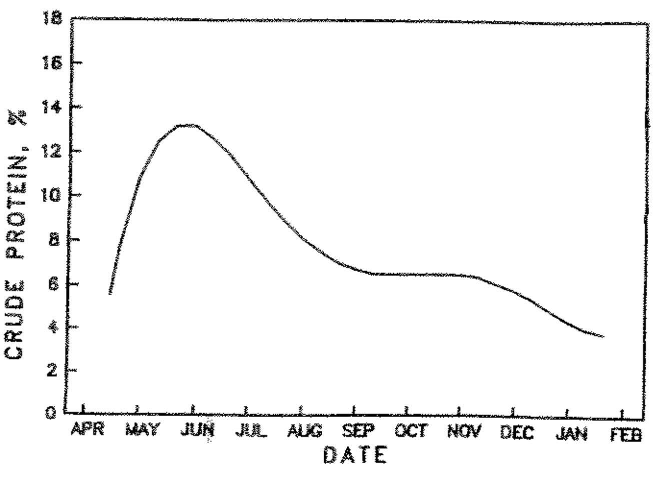
A number of studies have provided information for the development of management and nutrition strategies for range cattle. Our research showed greater forage and weight gain of yearling cattle per acre from contour furrowed range vs. native range; however, gains per individual animal were similar for both native range and contour furrowed range (Kartchner et al. 1983). A 4-year study evaluated combinations of crested wheatgrass, Russian wildrye grass, and contour furrowed rangeland with native rangeland on animal performance from calving to weaning (Adams et al. 1989). In this study, fall pregnancy rate and animal gains were similar for all forage combinations, primary benefits from the seeded and contour furrowed rangeland were deferment of early spring grazing on native range and increased stocking rate. Severe drought conditions persisted during one of the 4 years of the fore-mentioned study. During the severe drought, calves were weaned in July at about 80

[1] Author was formerly a Range Nutritionist at Fort Keogh Livestock and Range Research Laboratory and is presently affiliated with the University of Nebraska, West Central Research and Extension Center, Route 4 Box 46A, North Platte, Nebraksa.

days of age. Barley grain either rolled or whole or whole oats were fed free choice with alfalfa hay. Results of this study (Staigmiller and Adams 1989) showed that if drought or other management decisions mandate early weaning, calves can be fed on the ranch with minimum labor, equipment, or feed processing to obtain satisfactory growth.

A model was developed from diet samples collected from esophageally fistulated cattle over a 10-year period to predict dietary crude protein of cattle grazing native range (Adams and Short 1988; Figure 1). This model shows ample protein concentration during May, June and July to support relatively high levels of growth and lactation. During August through October, the protein would be expected to support only modest gains, or production, or maintenance only. During winter months dietary protein was in the 3 to 4% range, which could be expected to be suboptimal for digestion and intake of range forage. Supporting our interpretation of the diet model, research with rumenally fistulated animals showed that rumen NH_3-N levels during August and into the fall and winter were near or below levels suggested as optimum for forage digestibility (Adams et al. 1987a; Ward et al. 1990a; Ward et al. 1990b). When supplemental protein was fed, rumen NH_3-N level and digestibility of winter increased. A study (Adams and Kartchner 1984) conducted in drylot which related level of intake with rumen NH_3 concentration and rumen fluid volume was of value in interpreting rumen NH_3-N data in grazing trials.

Figure 1. Concentration of crude protein in cattle diets at various times of the year on Northern Great Plains rangeland.



Our research with cattle during the winter demonstrated that energy (grain) supplements lower and protein supplements increase intake and digestibility of range forage by cattle when compared to non-supplemented cattle (Kartchner 1980; Ward et al. 1990b). We concluded from our supplementation studies that feeding grains to cattle grazing winter range may be of little value. However, we found negative effects of feeding corn grain on change in body weight and body condition were significantly reduced by feeding the grain daily rather than on an alternate day basis (Adams 1986). Protein supplements fed during the winter improved the energy status of the cow by increasing the amount and digestibility of the forage consumed. Our studies showed a large beneficial effect on maintenance of body condition and body weight from feeding various sources of supplemental protein including soybean meal (Kartchner 1980), a cottonseed meal-barley pellet or alfalfa hay cubes when compared to non-supplemented cattle (Cochran et al. 1986a).

During the late summer and early fall when forage quality was greater than expected during the winter, daily gain of yearling steers was improved by .5 pound/day by feeding 2 pounds of corn at 1:30 p.m. versus feeding 2 pounds of corn at 7:30 a.m. or feeding no supplemental corn (Adams 1986). Steers fed in the p.m. consumed more forage and total energy than did steers fed in the a.m. or not fed supplement.

In some of our most fascinating research, we found that as ambient air temperatures declined from 32° to -40°F that the time cattle spent grazing during the day declined linearly (Table 2). As wind speed increased, a further reduction of grazing time was noted (Adams et al. 1986). This decline in grazing time was accompanied by a large reduction (up to 50%) in forage intake. Cow age (Adams et al. 1986) and body size of the cow (Adams et al. 1987c) influenced grazing behavior. Effects of cold on grazing behavior were greater for younger and smaller cows. Body condition of the cow did not influence grazing behavior. Forage intake per unit of body weight was greater for smaller (1000 lb) than larger (1290 lb) and for thinner than fatter cows (Adams et al. 1987c).

Table 2. Predicted daily grazing time of cows at various air temperatures and wind velocities.

Minimum Daily Temperature °F	Average Daily Wind Velocity (MPH) 0	5	10	15
30	9.1	8.8	8.4	8.0
15	8.1	7.8	7.4	7.0
0	7.1	6.7	3.4	6.0
-15	6.0	5.6	5.3	4.9
-30	5.0	4.6	4.3	3.9

Conclusions

Much of the range nutrition research at Miles City has been summarized and integrated with other research in various symposium or proceedings (Adams and Short 1988; Adams 1987; Cochran et al. 1987b; Adams 1989, Cochran et al. 1986). When the knowledge gained from these studies is put into practice, producers will benefit through more efficient use of their feed resources and reduced production costs.

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Effect of the 1988 Drought on Seeded Rangelands in the Northern Great Plains

M.R. Haferkamp, P.O. Currie, J.D. Volesky, B.W. Knapp and K.R. Peterson[2]

Introduction

The Northern Great Plains area near Miles City, Montana, experiences frequent periods of drought (Fig. 1). The area received 1.8 inches of rainfall in August 1987 and then received only 1.7 inches of precipitation during the period from September 1987 through March 1988, setting the stage for a dry growing season (Fig. 2). Past records on response of vegetation to drought in this area (Ellison and Woolfolk 1937; Whitman et al. 1943; Hurtt 1951; Reed and Peterson 1961) show plants go through alternating periods of dormancy and growth and production is reduced during years with limited precipitation. Actual die off or loss of plant basal area sometimes occurs for many native species such as blue grama (Bouteloua gracilis), western wheatgrass (Agropyron smithii), buffalo grass (Buchloe dactyloides), and needle-and-thread grass (Stipa comata) if the drought is severe. Populations of other species such as Sandberg bluegrass (Poa sandbergii), prairie junegrass (Koeleria cristata), and thread leaf sedge (Carex filifolia) may increase or remain stable during these drought periods, since they grow primarily during early spring when some soil moisture is available and then quickly go dormant when soil moisture is lacking.

Many acres on the northern Great Plains, are also seeded to introduced grasses such as crested wheatgrass (Agropyron desertorum) and Russian wildrye (Psathrostachys juncea). These two species were reported by Currie and White (1982) to be more drought resistant than many of the species recommended for seeding in the area. Reports, however, from both Colorado (Currie 1970) and Canada (McLean and van Ryswyk 1973) indicated death loss of these grasses can occur during drought years.

The objective of this study was to determine the potential death loss incurred on stands of crested wheatgrass and Russian wild rye during the summer and early fall of 1988 in the northern Great Plains.

Methods

Potential survival of plants was determined by collecting plants in the field, watering them and then maintaining them in controlled environments for at least 25 days. Plants were collected from the Rosebush pasture on the Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana. Soils of these pastures are described as Havre Variant loam, Benz loam, and Havre Variant-Busby Variant complex. Nordan crested wheatgrass was drilled at 6.5 lb/acre on 14-inch centers in 1978 and Vinal Russian wildrye was drilled at 6.5 lb/acre on 21-inch centers.

One hundred 'dormant' plants of each species were collected on 11 July, 23 August, and 22 September 1988. Plants were dug with a tile spade at 10 to 20 step intervals across the pasture. Care was used to expose a minimal amount of roots. Each plant was promptly placed into a plastic pot, brought to the laboratory and soaked with distilled water. Twenty-five plants of each species were randomly allocated to one of four environments for the 25 day period. These plants were (1) kept on a table outside; or in chambers with controlled environments of (2) 41-59°F, (3) 50-68°F, or (4) 59-77°F; with 12 hours of dark during the low temperature and 12 hours of light during the high temperature.

Daily records were kept on the number of plants developing green shoots. Water was added as needed to keep the soil moist. At the end of the incubation period, plant basal areas were estimated, green shoots were counted, clipped at the base, oven-dried, and weighed.

In addition to monitoring plants in the growth chambers, the percentage of live plants remaining in each pasture, was estimated following rains in September. Estimates were made by determining the number of dormant and green plants occurring in 12 x 12-inch plots randomly distributed across the pastures. Environmental conditions for the general area were monitored at local weather stations.

Results and Discussion

The Miles City area received 2.8 inches of precipitation during the period, April-September 1988 with 1.1 inch occurring in September (Fig. 1). This amount was 30% of the long term average of 9.4 inches generally received during this same time period. Temperatures during this period were also higher than normal; with maximum temperatures of 100°F + occurring on 23 days.

Plants collected in July began growth relatively soon after watering. Russian wildrye plants produced green shoots rapidly, and over 20 plants had produced shoots in 10 days in all environments except the 41-59°F treatment where it took 14 days to produce any shoots. By day 20, 23 out of 25 wildrye plants had produced shoots in all environments. In comparison, fewer than 20 crested wheatgrass plants greened up. They also grew at a slower rate than Russian wildrye plants.

Plants which were left in the field an additional 43 days in the dry-hot environment (sample date 23 August) suffered additional and severe death loss. During this dry period maximum temperatures were over 100°F for 14 days, and only .33 inch of precipitation was received. Also plants collected in August grew at a much slower rate than those collected in July. The maximum number of plants producing green shoots was reduced 62% for Russian wildrye and 31% for crested wheatgrass.

[2] Authors are: Haferkamp is a Plant Physiologist, Currie is a Retired Range Scientist, Knapp is a Statistician and Peterson is a Research Associate in Range at USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana. Volesky is a Range Scientist, Forage and Livestock Research Laboratory, El Reno, Oklahoma.

Figure 1. Total and average precipitation for selected periods at Miles City, Montana for 1877 through 1989.

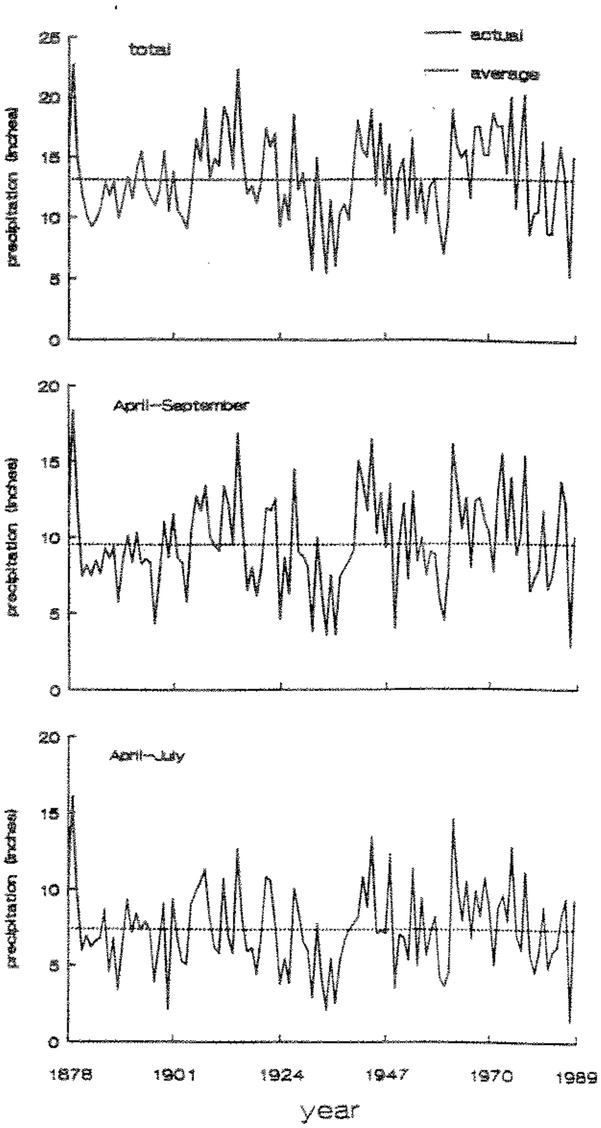
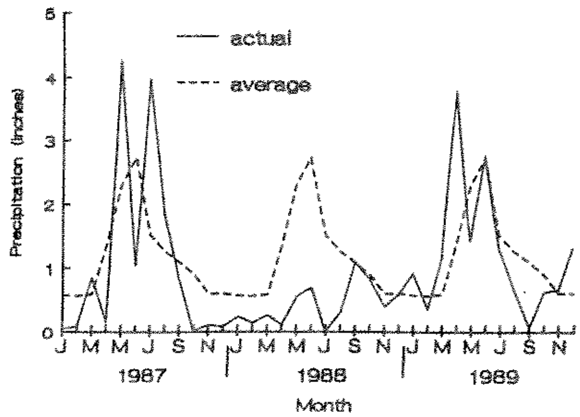


Figure 2. Seasonal distribution of precipitation for 1987 through 1989 for Miles City, Montana.



September collections were made after the site received .98 inch of precipitation, and a cooling trend had occurred. However, only 16% of 100 plots on the crested wheatgrass pasture and 163 plots on the Russian wildrye pasture contained green plants. When the dormant plants were collected and incubated at the laboratory, 21% of the Russian wildrye and 7% of the crested wheatgrass plants produced green shoots in 20 days. Rate of greenup was relatively slow in all environments. These data suggest that over 70% of the crested wheatgrass plants and over 60% of the Russian wildrye plants were lost during the drought. The most severe loss seemed to occur in late July and early August.

Conclusions

These findings show significant losses of plants occurred on some ranges seeded to crested wheatgrass and Russian wildrye during the 1988 drought in the Northern Great Plains. Residual seeds were adequate for natural seeding on some stands, but seeding was required on others to provide productive stands needed for post calving pastures. Land managers need to be aware of this potential loss during similar drought periods in the future.

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LATE SUMMER FORAGE VALUE OF GRASSES ADAPTED TO SALINE-SODIC SOILS OF THE NORTHERN GREAT PLAINS

M.M. Borman, D.C. Adams, B.W. Knapp, and M.R. Haferkamp[3]

Introduction

Several introduced perennial grasses have potential for use on the 90,000 acres of saline-sodic soils in the Northern Great Plains. Before seeding extensive areas to one or more of these introduced grasses, it would be of value to producers to have information concerning nutritive values and livestock preferences of the grasses being considered. During late summer and early fall, native rangelands normally do not provide adequate nutrition for young, growing livestock. This study was designed to evaluate 6 saline-sodic soil adapted grasses for their nutritive values and preferences by lambs at the late summer green, mature stage of development and following regrowth after late summer harvest.

Methods

Six introduced, cool-season, perennial grasses were utilized in this study. The 6 grasses were 'Jose' and 'Orbit' tall wheatgrass (Agropyron elongatum), 'Garrison' creeping foxtail (Alopecurus arundinaceus), 'Kenmont' tall fescue (Festuca arundinacea), 'Vinall' Russian wildrye (Psathyrostachys juncea), and a quackgrass X bluebunch wheatgrass hybrid (Agropyron repens X spicatum) which will be referred to as RS hybrid. The grasses were mowed to a 2 inch stubble height in August 1985. The material was chopped into 2 inch lengths. Regrowth was mowed and chopped in a similar manner in September.

Laboratory analyses were conducted to determine the percent composition of each for dry matter, organic matter, crude protein, neutral detergent fiber, acid detergent fiber, acid detergent lignin, and gross energy. Percent dry matter is the part of the grass which is not water. Percent organic matter is the part of the plant which contains carbon as part of the structure. Crude protein is total nitrogen multiplied by 6.25 based on the fact that feed protein on the average contains 16% nitrogen. Neutral detergent fiber (NDF) is primarily the cell walls of a plant after the cell solubles have been removed. Cell solubles are almost completely digestible. Components of neutral detergent fiber range from readily digestible in the rumen to not digestible. Acid detergent fiber (ADF) is composed of cellulose, lignin and lignified nitrogen. Hemicellulose and fiber-bound protein, which are partially digestible, have been removed from ADF. Acid detergent lignin (ADL) is the part of the plant fiber that is totally unavailable to the animal (i.e. the animal cannot digest it). Gross energy is the total amount of energy contained in the plant. It does not in any way reflect energy available to the animal. In vitro dry matter and organic matter digestibilities were also determined in the lab. In vitro digestibilities are determined in the lab by digesting feed materials in rumen fluid that has been extracted from a steer. Two digestibility trials with lambs were conducted to determine dry matter, organic matter, neutral detergent fiber, protein and energy digestibilities. In the digestibility trials, the amount of a nutrient in the feces is subtracted from the amount of the nutrient in the feed actually eaten to determine the amount of that nutrient apparently digested. In trial 1, grasses were at the mature, green stage of development. In trial 2, they were in a vegetative, regrowth stage of development.

Lambs (115 lb. average weight) were used to evaluate preference for the following 4 grasses: Jose and Orbit tall wheatgrass, Garrison creeping foxtail, and Kenmont tall fescue. Material from the initial harvest of green, mature grass mowed to a 2 inch stubble height and chopped into 2 inch lengths was used. Two trials were conducted to evaluate preference. In the first trial, all four grasses were included. Following trial 1, the most preferred species were removed and a second trial conducted to evaluate the 3 remaining species. An experimental design was used that allowed us to account for differences due to animal, day, pen, and grass placement within a pen.

Results

Nutritional values of the 6 grasses at both mature and vegetative, regrowth stages of development are presented in Tables 1 and 2. Nutritive values at the green, mature stage of development were not significantly different among the grasses. During regrowth, crude protein levels of Kenmont tall fescue and Orbit tall wheatgrass were lower than for the other 4 grasses. With that exception, nutritive values of regrowth were not significantly different among the 6 grasses.

Apparent digestibilities of the grasses at the mature stage of development are presented in Table 3. Dry matter and organic matter digestibilities of Jose tall wheatgrass were significantly greater ($P < 0.10$) than for Garrison creeping foxtail. Neutral detergent fiber digestibilities of Orbit and Jose tall wheatgrasses and Vinall Russian wildrye were significantly greater ($P < 0.10$) than for RS hybrid, Garrison creeping foxtail, and Kenmont tall fescue. Energy digestibilities for Orbit and Jose tall wheatgrasses tended to be higher than for Garrison creeping foxtail ($P < 0.10$).

Apparent digestibilities of the grasses at the vegetative, regrowth stage of development are presented in Table 4. Dry matter digestibility of Jose tall wheatgrass was low ($P < 0.10$) relative to the others. Protein digestibilities were high for Jose tall wheatgrass, RS hybrid, and Vinall Russian wildrye and low for Kenmont tall fescue relative to the others. Neutral detergent fiber digestibilities were high for Vinall Russian wildrye and Garrison creeping foxtail and low for the 2 wheatgrasses relative to the others.

Since no one grass stood out relative to the others with respect to all nutritional factors and digestibilities, selection based on these factors as a group would not be warranted. Digestible energy and protein of the grasses at both mature and regrowth stages of development relative to growth requirements for 110 lb. lambs are

[3] Borman is a Postdoctoral Research Associate in Range Science, Knapp is a Statistician and Haferkamp a Plant Physiologist at USDA-ARS, Fort Keogh Livestock and Range Research Laboratory. Adams is Range Nutritionist, University of Nebraska.

Table 1. Nutritional values of green, mature grasses when cut in August 1985.

Species	% dry matter	% of dry matter: organic matter	crude protein	neutral detergent fiber	acid detergent fiber	acid detergent lignin	in vitro dry matter digestibility	in vitro organic matter digestibility	gross energy (Mcal/lb)
RS hybrid	94.06	92.31	7.39	67.67	38.00	3.74	60.02	59.63	1.98
Vinall Russian wildrye	93.68	92.11	8.57	67.66	41.74	4.13	56.26	57.19	1.97
Garrison meadow foxtail	94.64	91.05	8.24	64.60	39.50	3.72	59.90	60.15	1.92
Kenmont tall fescue	94.19	90.40	7.87	66.63	39.70	3.35	59.50	59.60	1.88
Orbit tall wheatgrass	94.41	91.81	7.53	68.29	41.56	3.45	60.37	59.52	1.91
Jose tall wheatgrass	94.55	91.56	7.21	68.39	42.53	3.84	60.52	60.65	1.92

Table 2. Nutritional values of grass regrowth following harvest in August 1985.

Species	% dry matter	% of dry matter: organic matter	crude protein	neutral detergent fiber	acid detergent fiber	acid detergent lignin	in vitro dry matter digestibility	in vitro organic matter digestibility	gross energy (Mcal/lb)
RS hybrid	94.65	88.56	13.87	53.91	34.29	4.37	66.15	64.03	1.96
Vinall Russian wildrye	94.64	86.19	14.95	66.28	39.25	4.84	63.00	60.90	1.93
Garrison meadow foxtail	95.69	87.16	11.08	58.29	36.80	4.13	66.77	65.10	1.90
Kenmont tall fescue	95.61	87.67	8.26	54.70	33.47	2.96	67.05	64.24	1.82
Orbit tall wheatgrass	95.76	87.90	9.90	58.08	38.60	4.66	66.63	63.54	1.88
Jose tall wheatgrass	95.92	83.09	11.24	58.74	41.20	4.82	60.10	56.56	1.80

Table 3. Apparent digestibilities (%) of green, mature grasses when cut in August 1985.

Species	dry matter	organic matter	neutral detergent fiber	protein	energy
RS hybrid	59.4	60.9	55.4	70.0	57.0
Vinall Russian wildrye	60.2	61.6	60.9	69.4	57.2
Garrison meadow foxtail	57.5	59.4	55.0	72.1	54.8
Kenmont tall fescue	58.3	60.2	56.0	72.3	56.1
Orbit tall wheatgrass	60.3	62.9	61.4	70.3	58.7
Jose tall wheatgrass	62.0	64.1	62.5	71.6	60.4

Table 4. Apparent digestibilities (%) of regrowth of grasses following harvest in August 1985.

Species	dry matter	organic matter	neutral detergent fiber	protein	energy
RS hybrid	59.3	62.6	53.3	74.7	57.2
Vinall Russian wildrye	59.1	62.9	62.6	74.1	58.1
Garrison meadow foxtail	61.1	65.3	60.3	69.5	60.0
Kenmont tall fescue	61.8	67.1	54.1	63.6	62.1
Orbit tall wheatgrass	58.0	62.7	50.1	70.8	58.5
Jose tall wheatgrass	54.3	63.3	49.1	76.5	59.0

presented in Figures 1 through 4. At the mature stage of development, all 6 grasses were deficient in both protein and energy. A protein supplement would be needed for adequate lamb growth and development. At the vegetative, regrowth stage of development, RS hybrid and Vinall Russian wildrye exceeded and Garrison creeping foxtail met digestible protein requirements. Kenmont tall fescue and the 2 wheatgrasses would require a protein supplement. All 6 grasses were deficient in digestible energy.

Results from the preference trials indicated that Jose tall wheatgrass was by far the most preferred of the 4 grasses evaluated at the green, mature stage of development (Table 5). Kenmont tall fescue was a distant second, but was much preferred over Garrison creeping foxtail and Orbit tall wheatgrass. There were no indications in the nutrient analyses (Table 1) or in the digestibility trial results (Table 2) that would suggest any reason for the very marked differences in preference. If grasses are to be harvested and included in a mixed ration for growing lambs, it appears that it would be very beneficial to have an indication of relative preferences. Grasses with low palatability may be rejected. Also of interest is the quantity of intake. Even the Jose tall wheatgrass fell far short of the approximately 4 lbs. per day of intake required for growing 110 lb. lambs. If these grasses are to be used as late season complementary forages, it appears that they will have to be supplemented or included as part of a mixed ration.

Table 5. Daily intake rates (lb/day) by grass species.

	Species	dry matter intake
	Jose tall wheatgrass	1.19
Trial 1	Kenmont tall fescue	0.11
	Garrison creeping foxtail	0.02
	Orbit tall wheatgrass	0.00
	Total	1.32
	Kenmont tall fescue	0.84
Trial 2	Garrison creeping foxtail	0.32
	Orbit tall wheatgrass	0.06
	Total	1.22

Conclusions

The 6 grasses evaluated in this study are adapted to saline-sodic soils. They are not adequate on a nutritional basis to function as late-season complements to native range unless they are supplemented or used as components in a mixed ration. Extreme differences in preference among the 4 grasses evaluated indicates that it would be very useful to have an idea of palatability of a grass if it is not to be wasted when utilized as part of a mixed ration. Nutritional analyses alone do not provide an indication of palatability. Rumen fill may be a problem if the grasses are fed as sole source of feed during late summer and fall.

Figure 1. Digestible protein required by 110 lb. growing lambs and digestible protein provided by 6 grasses at the green, mature stage of development.

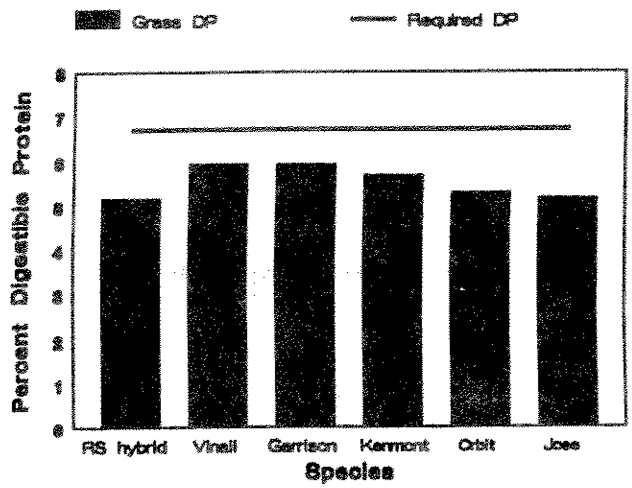


Figure 2. Digestible energy required by 110 lb. growing lambs and digestible energy provided by 6 grasses at the green, mature stage of development.

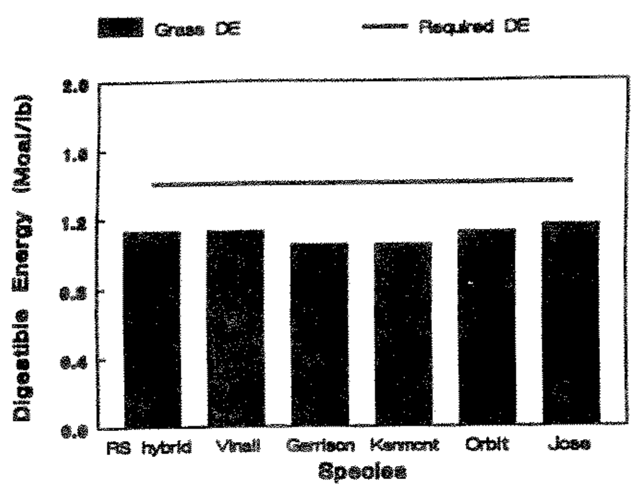


Figure 3. Digestible protein required by 110 lb. growing lambs and digestible protein provided by 6 grasses during August - September regrowth.

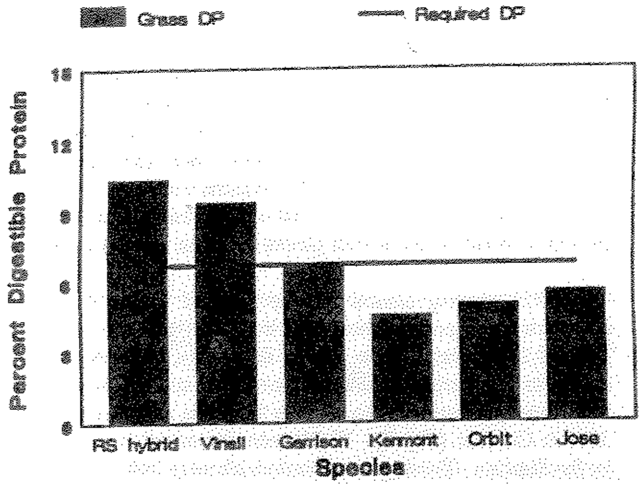
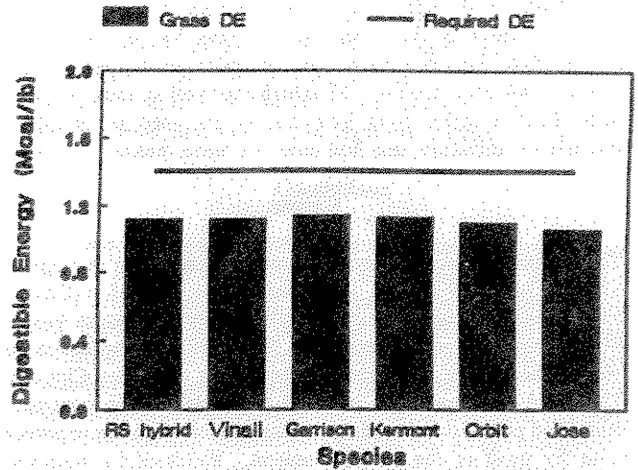


Figure 4. Digestible energy required by 110 lb. growing lambs and digestible energy provided by 6 grasses during August - September regrowth.



RESPONSE OF THE BLUEBUNCH WHEATGRASS-QUACKGRASS HYBRID TO FERTILIZATION AND DEFOLIATION

M.R. Haferkamp, D.C. Adams, M.M. Borman, P.O. Currie, B.W. Knapp and K.R. Peterson[4]

Introduction

The RS2-hybrid was developed by the USDA-ARS Crops Research Laboratory, Logan, Utah, by crossing the native bluebunch wheatgrass (Pseuduroegneria spicata) with the introduced sodformer quackgrass (Elytrigia repens). This hybrid has been grown successfully since 1981 in irrigated pastures on Fort Keogh LARRL (Currie et al. 1986). The RS2 is adapted to saline soils and is readily grazed by livestock. Comparable to other grass species, forage quality of RS2 declines as plants mature (Currie et al. 1986). Research with quackgrass showed the summer slump in forage quality could be moderated with a split application of nitrogen fertilizer applied twice a season (Schoper et al. 1979).Other studies have also shown defoliation by mowing or grazing can maintain plants in a vegetative state and produce higher quality forage. We conducted a study at Fort Keogh LARRL to determine how an irrigated pasture of the RS2 hybrid growing on a saline soil responds to fertilization and defoliation by mowing.

Methods

Separate areas of an irrigated pasture of the RS2 hybrid were treated in 1988 and 1989. In 1988, fertilizer treatments of 0, 100, and 200 lb/acre were applied on 5 June. A split season application of 100 lb/acre was applied on 13 September to one set of plots that had been fertilized with 100 lb/acre in June. The mowing treatments consisted of no mowing, or mowing to a 2-inch stubble height on 11 July or 24 August. Plant response was evaluated by measuring forage yields in June, July, August, September and December. Tillers were collected at 1- to 2-week intervals, oven-dried, and samples from 8 collection periods were sorted into leaf and stem components. Tiller samples from 14 of the collection dates were left intact. Leaf, stem and tiller components were weighed, ground and analyzed for nitrogen. Nitrogen is reported as percent crude protein (%N X 6.25).

During 1989, fertilizers were applied on 2 May, and the second application of the split 100 lb/acre treatment was applied on 1 August. Six mowing treatments were applied as follows: (1) May,

[4] Authors are: Haferkamp is a Plant Physiologist, Borman is a Postdoctoral Research Associate in Range Science, Currie is a Collaborator, Knapp is Statisitician and Peterson is a Research Associate at the USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana. Adams is a Range Nutritionist, University of Nebraska.

June, July, August, and September, (2) June, July, August, and September, (3) July, August, and September, (4) August and September, (5) September and (6) October. All treatments were supposed to be mowed again in October, but regrowth was not adequate to justify mowing. Plant response to treatment was monitored by measuring phenological development, forage yields, tiller density and height, and nitrogen content of leaves and stems for the 6 mowing dates and intact tillers for an additional 6 intermediate collection dates. Air temperature was measured at a nearby weather station. Moisture received as rain, irrigation water from a center pivot irrigation system used periodically to supplement moisture, and soil moisture were measured on site.

Results

The pasture received 1.3 inches of moisture as rain or as irrigation water in June, 1.9 in July, 1.1 in September, and 1.5 in October 1988. During August the center pivot irrigation system was not working and no rainfall occurred. The 1988 growing season was one of the hottest and driest on record in the Miles City area. These hot-dry conditions reduced plant yields. The control or unmowed plants developed slowly and remained in the vegetative state for most of the growing season. Yields of the unmowed controls increased from a low of 777 lb/acre on 29 June to a high of 2716 lb/acre on 7 September (Fig. 1). Plots, mowed on 11 July when yields averaged 1248 lb/acre, were yielding 270 lb/acre by 28 July and 1248 lb/acre by 13 December (Fig. 1). Plants mowed on 24 August grew only slightly during late fall. Fertilizer treatments did not appear to significantly increase production during 1988. The lack of response to fertilizer may have been due to past fertilization and grazing practices or the hot-dry environmental conditions. Yields were depressed to below 2768 lb/acre.

Crude protein contents remained high during the drought period when yields were low. Percentages of crude protein contained in sorted and unsorted tillers for the control plants that were neither fertilized nor mowed ranged from a high of 18.8 in June to a low of 10.4 in November (Fig. 2). Crude protein was consistently higher in samples from fertilized plots ranging from 19.7% in June to 12.1% in November and December. These values are quite high for forage in late fall and winter. Crude protein contents of leaves of unmowed plants ranged from 20.1% in late June to 12.5% in December. Plants mowed in early summer contained 26% crude protein in July and 14% in December, and ones mowed in late summer contained 27% in September and 16% in December. Fertilizer applied at 100 and 200 lb/acre increased crude protein content in leaves of plants mowed in July, but did not affect crude protein content of unmowed plants or those mowed in August.

The 1989 growing season was cooler and wetter than in 1988. Moisture from precipitation and irrigation totaled 2.49 inches in April, 2.15 in May, 0.15 in June, 1.65 in July, 1.0 in August and 0.6 inches in September. Yields of unmowed controls increased from 1809 lb/acre in late May to 4998 in late July, and then decreased to 3379 in October (Fig. 3). Yields were increased almost 900 lb/acre by fertilization. Total accumulated yields were 3032 lb/acre for plots mowed monthly from late May through September, 5590 for June through September, 5521 for July through September, 4485 for August and September, 4548 for September, and 3379 for October. Significantly lower yields were produced by stands mowed initially in May and October. Total yields were also increased 893 lb/acre by fertilization. Other researchers have reported total yields of other grass species are reduced when they are clipped or mowed early during inflorescence development, and yields are also less in late fall after leaf senescence occurs.

Figure 1. Seasonal yields of RS2 in 1988 on unmowed plots (defol. 1) and plots mowed on 11 July.

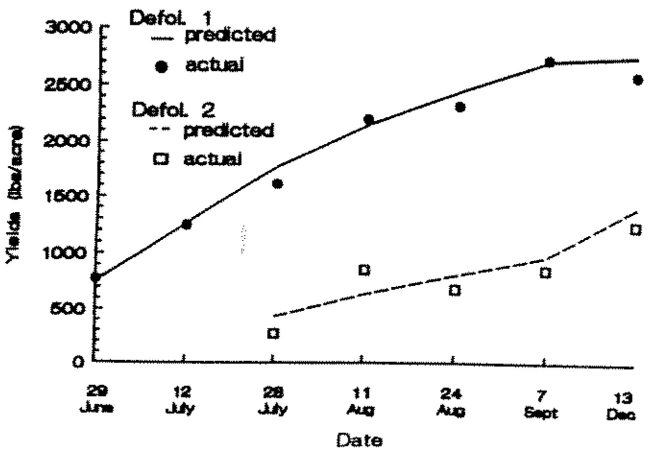


Figure 2. Predicted crude protein contents of sorted and unsorted tillers from unmowed control RS2 plants fertilized with 0, 100, or 200 lb N/acre or a split application of 100 + 100 lb N/acre in 1988.

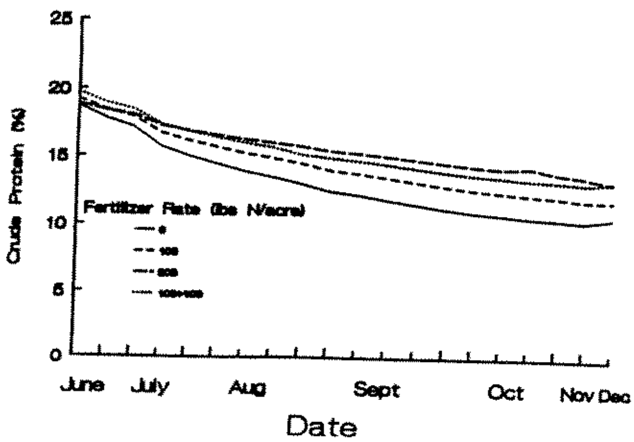
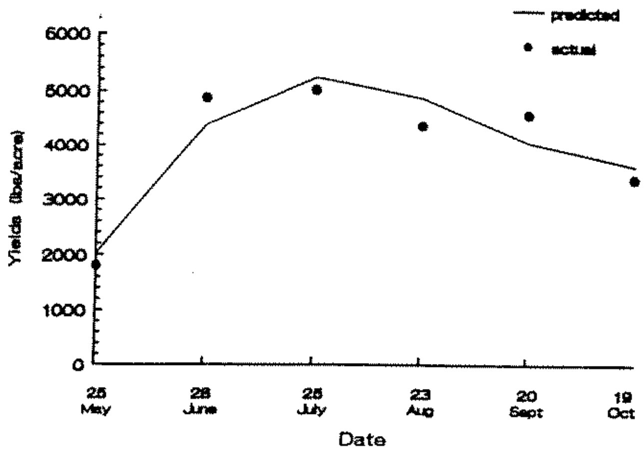
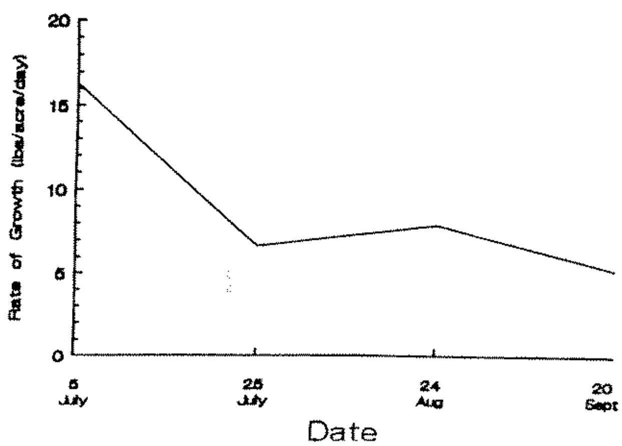


Figure 3. Seasonal yields of unmowed RS2 plots in 1989.



Regrowth following the first mowing ranged from 16.3 lb/acre/day for plants mowed in late May to 5.3 lb/acre/day for plants mowed in late August (Fig. 4). Regrowth following the second harvest was similar for plants mowed on the different dates averaging 11.0 lb/acre/day, but fertilization almost doubled the rate of regrowth when compared to the 7.0 lb/acre/day recorded for unfertilized controls. Although rate of regrowth was high for plants mowed in the 4-5 leaf vegetative stage in May, the amount of forage harvested from these plots was only 55% of the forage harvested from plots where the initial harvest occurred in late July and August when plants were in anthesis.

Figure 4. Predicted average rate of growth for RS2 plants following the first mowing applied on 25 May, 28 June, 25 July, or 24 August 1989.



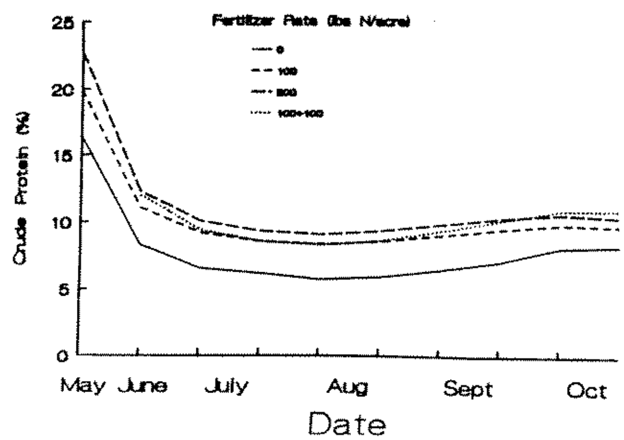
Crude protein contents were lower in 1989 than in 1988 in plants that had not been fertilized or mowed (Fig. 5). Percentages decreased from 16.4 in May to 5.3 in August. An increase to 8.4% in October resulted from greenup occurring with fall rains.

Fertilization consistently increased crude protein in RS2 plants (Fig. 5). Crude protein contained in leaves of unmowed plants decreased from 24.2% in May to 14.1% in August, and increased to 16.7% in October. When plants were mowed in May, June, July, and August, forage produced during the regrowth periods was in the 3-5-leaf vegetative stage and contained relatively high crude protein contents of up to 27%. Leaves produced during the first and second regrowth periods for plants harvested in May, June, July or August averaged over 25% crude protein, a value similar to the content of leaves harvested in May. Fertilizer increased crude protein in leaves harvested in the first and second regrowth periods by 2.6 to 4.1%.

Conclusions

Our results suggest that fertilization and season of defoliation can be used to increase forage production and quality on irrigated pastures of RS2 hybrid growing on saline soils in the Northern Great Plains. Fertilized pastures harvested in late June and July, rested and utilized again in fall or early winter could provide large amounts of relatively high quality forage for grazing livestock. Research is being continued to better define the impact of irrigation and defoliation in early and mid summer on the yield and forage quality of RS2 forage produced in the regrowth period, and its potential use as fall and winter forage.

Figure 5. Predicted crude protein contents of sorted and unsorted tillers from unmowed control RS2 plants fertilized with 0, 100, or 200 lb N/acre or a split application of 100 + 100 lb N/acre in 1989.



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ESTIMATING BODY COMPOSITION IN LIVE CATTLE

R.E. Short, W.L. Reynolds, B.K. Knapp, L.O. Crosby, W.E. Larsen, H.R. Duke and L.E. Orme[5,6]

Introduction

The amount of fat contained in beef cattle and their carcasses is important in determining quantitative and qualitative nutritional value of meat produced as well as production efficiency. Relative amounts of fat in an animal are often referred to as body composition although amounts of other components such as protein can also be included. In this discussion the term composition will mean the proportion of fat in a body or carcass.

Composition is important in determining quality of meat. Meat from maturity score A or B carcasses should have a minimum of 3% fat within the loin muscle for acceptable palatability and not exceed 7.5% so amount of fat consumed is not excessive (Savell and Cross, 1988). This recommendation considers only the fat within the muscle so total carcass composition would be higher. This range or "window" of acceptability would be comparable to USDA grades from low select (low good under the old system) to mid-choice. Palatability of cuts of meat from areas other than the loin or rib are not affected by composition.

Composition is also a major factor in determining the production efficiency of a cow-calf production unit (Short et al., 1990). Energy stored as fat is an insurance policy for cows against insufficient energy being available during times of environmental (extremes in temperatures) and production (lactation or deficient forage supply) stresses. In cases where fat reserves (condition score) are too low, there is a decrease in reproductive efficiency. Condition scores can also be too high because having excess reserves does not increase any measure of production. Efficiency of production systems where composition is too high will be lower because extra inputs invested in fat reserves will not increase returns.

Since composition is an important component of production efficiency and meat quality, it would be useful to be able to accurately measure composition in live animals. Topel and Kauffman (1988) reviewed over thirty methods for assessing composition in live cattle. They concluded that accuracies were only 60 to 80% and many of the methods were expensive and(or) impractical. Whatever methods are used they must be validated for the population of cattle being used.

The objectives of the following research were to develop new methods for evaluating composition of live animals and to develop prediction equations for composition using our population of cattle and existing as well new methods.

Materials and Methods

Experiment 1. Fifty mature, open, crossbred cows were fed varying amounts of a ration to obtain condition scores of two to ten (1=thinnest to 10=fattest) at the time of slaughter. A complete set of physical measurements was taken that included body weight, hip height, heart girth and condition score. Body water was estimated by urea dilution (Preston and Koch, 1973). In this procedure 60 gm of urea dissolved in water was injected into the jugular vein. Blood samples were taken before the urea was injected to get a baseline value and then at three minute intervals for 15 minutes to estimate body water by dilution. Urea concentration in samples taken at 3 and 6 minutes were more variable so were not used. Urea space was estimated by averaging the urea concentration of the 9, 12 and 15 minute samples, subtracting from that average the urea concentration of the preinjection sample, dividing the difference into 60 gm and converting to kg. The kg of US was then calculated as a percentage of body weight. Urea space or body water are related to composition because fat has a low water content as compared to lean tissue (muscle) which has a high water content.

The cows were then shipped from LARRL, Miles City, MT to Brigham Young University, Provo, UT where they were slaughtered within two weeks of the preslaughter measurements. At slaughter a complete set of tissue weights was recorded and the right half of the carcass was boned out and the soft tissue ground into hamburger. Samples were obtained from the hamburger which were analyzed for fat by the ether extract method. Composition was estimated by a weighted average of the fat content of the forequarter, hindquarter and 9-12 rib section. Data from one cow was incomplete so her complete data set was deleted from the analyses. The data were analyzed by correlation, standard partial correlations and multiple regression procedures.

Experiment 2. Eight mature cows, 8 two-year-old steers and 16 yearling steers were fed a moderate or high ration to result in a range of condition scores from moderate (4-7) to high (7-10). This set of crossbred cattle was used to evaluate the accuracy of an airtight chamber (plethysmometer) for estimating body volume, specific gravity and composition. Each animal was assigned a condition score by three trained technicians and then were weighed and volume measured three times each day for three days. The data were analyzed to get an estimate of repeatability (measurements must have high repeatabilities to be any good) and correlation with composition as estimated.

A plethysmometer is an airtight chamber constructed such that a known or constant amount of air can be injected into the chamber. This instrument is based on the Archimedean principle that an object displaces a volume equal to its own volume. A common way of utilizing this principle is to weigh an object under water. The difference between the weight in air and under water is the weight of water displaced by the object. This procedure of underwater weighing is often used to estimate volume and composition in

[5] Authors are: Short is Research Physiologist, Reynolds is Retired Geneticist, Knapp is Statistician from USDA-ARS Fort Keogh Livestock and Range Research Station, Miles City, MT. Crosby is at Neumedloc, Inc., Bryn Mawr, PA. Larsen is at Montana State University, Bozeman, MT. Duke is at USDA-ARS, Fort Collins, CO. Orme is at Brigham Yound University, Provo, Utah.

[6] Appreciation is expressed to the Montana Beef Council for providing some of the funds for this research.

humans, but for obvious reasons would not be practical for cattle or any nonhuman animal. Volume can also be measured from the amount of air displaced by an object. In this procedure (plethysmometry) when a known amount of air is injected into an airtight container, the rise in air pressure is proportional to the volume of an object in the chamber. This basis for a plethysmometer has been known for many years but instruments to very accurately measure changes in air pressure and computers to control operations and process data have not been available until recently.

A plethysmometer to hold cattle up to 2000 pounds was constructed and is often referred to as the "cow box". Entrance and exit doors with inflatable seals, door latches, self-catching head gate, a piston for injecting air and a vent to equalize chamber air pressure to atmospheric pressure are all operated by air cylinders controlled by solenoids. Air pressure and pressure changes are measured by a piezoelectric strain gauge transducer. The control of piston movement and air vent as well as collection and processing of data are by a portable computer with a 16 bit A/D converter board. The signal that comes from the transducer is analog or continuous and must be converted to digital for processing by the computer. The transducer and A/D converter are both manufactured here in Montana by Lawson Labs in Columbia Falls. A standard curve with known volume objects was developed using cylinders made from 12 inch irrigation pipe. The pipes were precision cut in a lathe to exact lengths and each end sealed with a flat piece of plastic.

Repeatability was estimated by correlation of repeated measures within an animal. Relationships among variables were measured using simple correlations. Effects of feed level and age were analyzed by analysis of variance.

Results

Experiment 1. In the initial analysis using multiple regression, hip height did not have any relationship precent fat (%F) so it was deleted from the model. The multiple regression analysis of the remaining measurements is shown in Table 1.

Condition score was by far the measurement that was most highly related to composition. High R^2 and low CP are statistical indicators of close relationships. The most accurate model was the one with four variables, but from a practical perspective, the two variable model accounted for almost as much variation (R^2=.89 vs .91). There is a problem in using an analysis such as this for this data set. This analysis assumes a cause and effect relationship shown in Figure 1. This relationship assumes that the variables on the left cause or create body composition. Those assumptions are not really true because the biological relationships are more apt to be as illustrated in Figure 2.

We can now see that composition causes or creates differences in the measurements rather than the other way around. Therefore other statistical methods may be more appropriate. These data were then analyzed using partial correlation coefficients which have the advantage that cause and effect relationships do not have to be assumed. This analysis is shown in Table 2.

Table 1. Relationship of measurements to body composition using multiple regression analysis.

Measurements in model	R^2	Mallo's CP
Condition Score (CS)	.86	21.25
Heart Girth (HG)	.75	72.19
Body Weight (BW)	.71	89.32
Blood Urea (U)	.32	277.71
Urea Space (US)	.20	333.43
CS + HG	.89	6.82
CS + HG + U	.90	4.34
CS + HG + U + US	.91	4.29
CS + HG + U + US + BW	.91	6.00

Figure 1. Relationship of variables to composition in a multiple regression analysis.

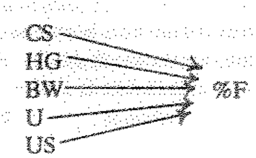
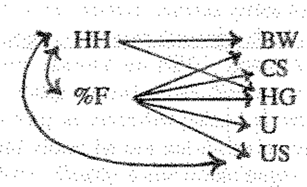


Figure 2. Biological relationships among the measurements with composition.



In this analysis we can see that condition score is still the most highly related to composition. The magnitude of this relationship and the order of importance of some of the other measurements are different than in the regression analysis. In this analysis the relationship between two measurements is adjusted to a standard value for all other measurements. For example, the partial correlation of condition score and percent fat is .80. This means that 64% ($.80^2$x100) of the variation in percent fat can be accounted for by CS with all other measurements held constant.

The relationship that condition score has to percent fat is illustrated in Figure 3. When condition score was less than 4 then percent fat was below 5%. As condition score increased percent fat increased so that in cows with condition score of over 9 the percent fat was greater than 30%. This set of cows had a large range in condition score. If we look at smaller segments of the range in condition score (i.e., condition score of 5 to 7), we can see that the relationship between percent fat and condition score may not be as good.

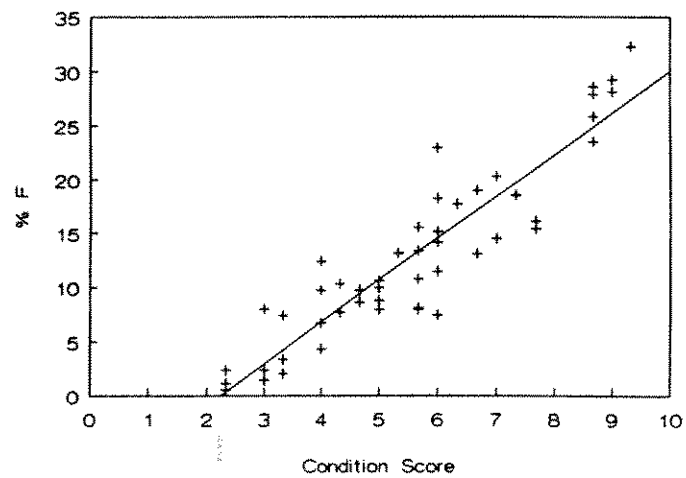
Table 2. Partial correlation coefficient matrix for the measurements[a] taken.

	%CF	HH	HG	BW	US	U
CS	.800**	-.166	-.176	-.203	.377*	.402**
U	-.410**	.015	-.269+	.240	-.600**	
US	-.345*	.337*	-.174	.320*		
BW	.256+	-.193	.800**			
HG	.067	.182				
HH	.057					

[a] %CF=% carcass fat, CS=body condition score, U=urea concentration before injection, US=urea space estimate of body water, BW=body weight, HG=heart girth, HH=hip height.

+ Probability that this correlation is real = .90
* Probability that this correlation is real = .95
** Probability that this correlation is real = .99

Figure 3. Relationship of composition (%F) to condition score.



Experiment 2. Repeatability of body volume measurements was high (.968) but less than that for body weight (.998). The effect of feed level and age is shown in Table 3.

Table 3. Effect of age and feed treatment on weight (BW, lb), specific gravity (SG) and condition score (CS).

Treatment	Age	Feed	BW	SG	CS
cows	mature	H	1550	1.07	9.0
		L	1243	1.11	6.6
steers	2	H	1378	1.10	8.2
		L	1153	1.12	7.2
	1	H	755	1.13	6.5
		L	693	1.15	5.9

Specific gravity decreased and condition score increased ($P<.05$) with increasing age and high feed level. There was a high correlation ($r=-.71$, $P<.01$) between condition score and specific gravity. Pressure readings for determining volume in the plethysmometer were sensitive to noise, breath cycles, air movement and temperature changes.

Discussion and conclusions

At present condition score is the best way to predict composition in live cattle with a wide range in composition. Accuracy can be improved by including heart girth with minor gains in accuracy by including blood urea concentrations and urea space. The gains obtained by the last two variables do not warrant the cost of those procedures. Care must be taken in using data such as this to predict composition if the relationships have not been validated for the population of cattle being used (Rule et al., 1986).

Plethysmometry estimates of volume can be used to estimate composition but more research needs to be done to improve accuracy and to validate the measurements against actual slaughter data.

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DEVELOPING REPLACEMENT BEEF HEIFERS TO ENHANCE LIFETIME PRODUCTIVITY

R.B. Staigmiller, R.E. Short and R.A. Bellows[7]

Introduction

Cows are culled from our nation's beef herds at an average age of 5 to 6 years old. If these cows were bred to calve first at 2 years of age, which most of them are, a producer has supported them for 40 to 50% of their life by the time they have weaned their first calf. That represents a very sizable "up front" investment. This becomes an extremely important investment in terms of the future of the cow herd, and there are several ways in which producers can protect this investment. First, they must use good judgment in selecting the right females in which to make the investment. If performance records are available on the dams, they can be used along with other criteria for selection of replacement heifers. Second, they need to establish a management plan for growing and developing the heifers that will enhance their lifetime productivity. The major emphasis of this discussion will be with management factors that influence lifetime productivity.

Several detailed studies have shown a lifetime production advantage to heifers that breed early and, as a result, calve early their first year. These early calvers tend to follow that pattern throughout their lifetime and tend to be older at culling than heifers which calve in the second half of the calving season the first year. As a result, these cows not only wean older and heavier calves, they also produce more calves than their slower-developing herdmates. These facts show a clear advantage of having the heifers reach puberty early and be ready to breed at the start of the breeding season.

Two studies have been conducted here at Miles City to look at fertility of the replacement heifer. These studies provide solid evidence for the need to have heifers at puberty early in relation to the breeding season.

Methods

Study 1. Over the period of several years we have noticed that some heifers each year will stand to be ridden by other heifers, indicating that they have reached puberty and are ready to breed, but have not continued to show evidence of normal estrous cycles. The first study was conducted to see if that was indeed occurring, and if so, how frequently.

One hundred forty-three crossbred heifers were placed in the feedlot after weaning and were fed a silage-hay-barley ration to gain 1.25 to 1.5 pounds per day throughout the winter. A sterile bull was penned with the heifers to detect when they were in estrus. As each heifer stood to be mounted by the bull or the other heifers she was given an examination that involved rectal palpations, similar to pregnancy testing, to determine an ovulation point on the ovary. It also included taking a blood sample to determine if a common hormone (progesterone) found after ovulation was present as it should be. Those animals that stood to be mounted but did not ovulate or did not show the appropriate levels of progesterone, were considered to have shown a non-puberal estrus (NPE). Hence, they were considered not to have actually reached puberty. All heifers were monitored throughout the entire wintering period to determine if they showed repeated NPE or if they showed normal estrous cycles.

Study 2. Several lines of evidence over the last 20 years have suggested that heifers may not conceive as readily if they are bred on their very first estrus (puberty) as they would if they were bred at some later estrus. This study was designed to determine fertility rates at puberty compared to a later estrus.

One hundred fifty-six heifers were assigned to be bred at either their first (puberal) estrus or at their third estrus.They were fed as in study 1 and were examined at estrus to determine ovulation as in study 1. Pregnancy tests were done at 45 to 60 days after breeding. The same bulls were used to breed both groups of heifers.

Results

Study 1. Examination of the heifers at puberty showed that non-puberal estrus was indeed occurring. Although the heifers would stand to be mounted, 32 out of 143 (22 percent) did not ovulate at their first estrus. This was further confirmed by the blood samples which showed that the hormone progesterone was not present at the levels it should be for normal estrous cycles to occur. Furthermore, it was not possible to forecast the reproductive performance of the heifers after they showed an NPE. Some heifers showed several NPEs before starting normal cycles. Some went completely anestrus (no cycles at all) for an extended period of time. When cycles began again they could either be normal cycles or on occasion they could have another NPE. Finally, some would begin normal cycles after an initial NPE. Since this information has become known other reports have shown that under some conditions, as high as 60 percent of the heifers in a herd have had an NPE.

These results tell us that not all heifers that stand to be ridden are ready to conceive when they are bred. In spite of showing outward signs of having reached puberty these heifers will not become pregnant. These results help us understand that if heifers are just starting to cycle as the breeding season is ready to begin, some of them will be delayed in getting pregnant and will calve later with lighter calves.

Table 1. Conception rates following mating at the first and third estrus.

Estrus Period	Conception Rate
First	57 %
Third	78 %

[7] Authors are Research Physiologists at USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana.

Study 2. Results of breeding at the first and third estrus are shown in Table 1.

It is clear that the conception rate is lower at puberty than it is after the heifer has shown several estrus cycles. This provides further information on why it is necessary to have the heifers cycling well before the breeding season starts to insure the best possible conception rates.

Conclusions

It should be obvious from these studies that it is not enough to simply have the heifers reaching puberty at the start of the breeding season if maximum conception rates are to be achieved. Heifers need to be wintered in such a manner that they will have reached puberty at 4 to 6 weeks before the start of the breeding season to avoid the lack of fertility of NPE and the reduced fertility of breeding at the first estrus.

STUDIES OF CALVING DIFFICULTY

R.A. Bellows, R.B. Staigmiller and R.E. Short[8,9]

Introduction

Calf deaths caused by difficult calving (dystocia) result in a major reduction in the net calf crop and income realized by beef producers. Based on 1989 projected figures, a 5% increase in animals available for sale could potentially increase gross receipts by $1.85 billion annually. These same projection figures also suggest that the losses attributed to calf deaths from dystocia alone exceed $850 million annually. Identifying ways to decrease dystocia and the accompanying calf deaths is the subject of this paper.

Associated Factors

Early work demonstrated that dystocia is affected by two categories of factors: (1) those attributed to the dam, and (2) those attributed to the calf. Of factors of the dam, precalving weight and pelvic area were the most important. For calf factors, calf sex and birth weight were the most important. All of these were statistically significant, and Table 1 shows the relative importance of the four factors. Note calf birth weight was the most important. This means that any effort to reduce the incidence of dystocia _must_ include controlling calf birth weight. However, notice that the precalving weight of the dam also had a negative effect on dystocia indicating that heavier (larger) dams had less dystocia. This means that growing the heifer adequately during the 2 years prior to calving is another important aspect of managing dystocia. Replacement heifers that are not fed and managed properly will be lighter (smaller) at calving and experience more dystocia.

Calf sex was also important. The research indicated that heifer calves were associated with fewer calving problems than were bull calves. However, since calf sex is determined at conception, we are not able to do much about this problem unless calf sex control can be achieved. This is not an impossible scenario since procedures for sexing semen and(or) embryos appear promising. Production of only female calves from first-calf heifers would potentially reduce dystocia.

The precalving pelvic area of the dam also had a significant negative effect on dystocia meaning that dams with larger pelvic areas experienced fewer dystocia problems. This relationship is shown graphically in Figure 1. Note that as pelvic areas became larger, the incidence of dystocia declined in all birth weight classes. This is an important relationship, but we must study all data available before we draw far-reaching conclusions.

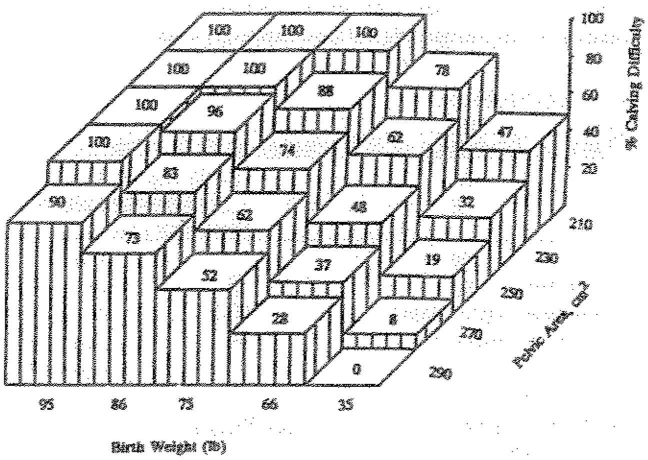
First, our data, and that of other scientists, show the following: (1) larger heifers produce calves with higher birth weight and, remember, high calf birth weight is the most important factor causing dystocia; (2) larger heifers have larger pelvic areas; but (3) heifers with larger pelvic areas produce calves with higher birth weights. This seemingly circular relationship must also be evaluated in light of data showing the genetic correlation between heifer size and birth weight and heifer size and pelvic area are relatively large and positive. These facts are of critical importance when we consider selecting breeding males and females for larger pelvic areas. Our studies show that larger pelvic size of the dam is associated with larger dimensions of the entire skeleton (Table 2). Pelvic height, width and area are skeletal growth traits, and there is little likelihood that selection for these traits will result in an increase in pelvic size only. The result will be larger total skeletal size, i.e., an increase in frame score. In addition, pelvic area of the dam at 231 days of gestation and at calving were positively associated with all skeletal traits plus placental and skeletal size of the calf (Tables 2

<u>Table 1. Relative importance of factors affecting dystocia in first-calf 2-yr-old heifers.</u>

Factor	Relative importance rating
Dam precalving weight	1.10
Dam precalving pelvic area	1.16
Calf sex	1.00
Calf birth weight	3.05

[8] Authors are Research Physiologists at USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana.
[9] Appreciation is expressed to the American Angus Association for financial support of this work.

Figure 1. Relationships among pelvic area, calf birth weight and percent calving difficulty.



and 3). These results mean that the increased skeletal size of the dam will be transmitted to the calf resulting in higher birth weights. Therefore, producers must be aware of what will accompany selection for pelvic areas. We have calculated that a 10-cm^2 increase in pelvic area would be accompanied by a .02 decrease in calving difficulty score and a 2-lb. increase in calf birth weight. The effect on dystocia score is small but desirable. However, there is a real possibility that the accompanying increase in calf birth weight would eventually cancel any gains realized from increases in pelvic area.

Table 2. Residual correlations between dam pelvic area at 231 days of gestation and carcass and fetal traits.

	r values
Dam pelvic area and:	
Live weight	.60**
Hot carcass weight	.43**
Carcass length	.41**
Shank length	.38**
H-bone length	.40**
Rear leg length	.33*
Rib lean weight	.26†
L. dorsi weight	.29†
Fetal:	
Placentome weight	.46**
Avg. placentome weight	.42**
Cannon circumference	.37*

† $P < .10$; * $P < .05$; ** $P < .01$.

Table 3. Residual correlations between dam size and calf dimensions.

		Dam precalving:	
		Body weight	Pelvic area
Precalving pelvic area		.58**	---
Calf:	Birth weight	.40**	.35**
	Head width	.31**	.16
	Head circumference	.44**	.30**
	Heart girth	.30**	.22**
	Hip width	.35**	.41**
	Body length	.35**	.34**
	Leg length	.27**	.35**
	Thigh width	.29**	.25**

** $P < .01$.

This is also important since much interest has developed in using pelvic areas to predict calving problems. Using pelvic area alone has been of minor value in predicting dystocia at Fort Keogh Livestock and Range Research Laboratory. The reason being that we cannot accurately predict calf birth weight. There are two prediction outcomes that must be considered: (1) identifying heifers that will not experience dystocia; (2) identifying heifers that will experience dystocia. We have been slightly more successful (+10%) in predicting heifers that will not experience dystocia than heifers that will experience dystocia.

Other scientists have more recently developed computer models that are of higher accuracy in predicting dystocia. These models involve cow age, external body dimensions, pelvic measurements and estimated calf birth weight. We need to watch these developments carefully since the field of computer modeling is very dynamic and will likely lead to valuable breakthroughs in decision making. However at the present time, the best methods of managing dystocia are: (1) raising the replacement heifer on a management program that allows maximum rates of fertility and skeletal growth; (2) controlling calf birth weight through wise sire selection; (3) do not underfeed or overfeed the pregnant heifer during gestation. Let's discuss these factors in more detail.

Table 4 shows a summary of a Miles City study of feed effects on puberty, reproduction and dystocia in Hereford-Angus crossbred heifers. Note that the winter rate of gain had marked effects on pregnancy rate. However, there were interesting effects on precalving pelvic area and incidence of dystocia. Since the heifers were all treated alike following the winter diet treatments, the calving data shows an important carryover effect of the dietary level. Development of heifers on the low feed level was retarded, and they had smaller pelvic areas at calving and a higher incidence of dystocia.

Point 2 (above) is in regard to sire effects on birth weight and dystocia. When EPD (expected progeny difference) values are available, average birth weight can be predicted with reasonable accuracy. Table 5 shows results of a Miles City study where we selected Angus bulls for moderate or high birth weight based solely on EPD values. Note that birth weight and dystocia percentages ranked as predicted. Note also that the study demonstrated the well-known relationships between prenatal and postnatal growth. The gestation lengths were essentially the same between the two sires so the differences in birth weights resulted from different growth rates of the fetus while in the uterus. This same ranking for growth rate continued after the calf was born resulting in differences in weaning weight and carcass weight and value.

Table 4. Effects of postweaning diet on reproduction, pelvic area and dystocia in heifers.

	Winter diet group[a]	
Data	Low	High
Number of heifers	30	59
Data gain - winter (lb./day)	0.6	1.3
Daily gain - summer (lb./day)	1.3	1.0
October pregnancy (%)	50	86
Calving data		
Precalving pelvic area (Cm^2)	240	252
Dystocia (%)	46	36

[a] Fed first winter period from weaning to breeding as yearlings.

Thus, the producer must make a decision as to how much growth rate he is willing to sacrifice to manage dystocia or how much dystocia he is willing to accept in order to maintain maximum growth. Use of EPD's can be of great value when available. When EPD's are not available, then birth weight of the potential sire can be evaluated as this gives a fairly accurate method of predicting and ranking birth weights. Sires can also be ranked by using an index (Index = adjusted yearling weight - 3.2 X birth weight). The yearling weight must be adjusted for age of dam. It is thought that use of this index will continue to increase postnatal growth rate and, at the same time, reduce the expected increases in calf birth weight by about 55%.

Point number 3 (above) is in regard to the gestation diet for the pregnant heifer. I have reviewed seven studies summarizing research in the U.S. and Australia that were specifically designed to study effects of gestation feed level. Feeding was for as long as 150 days or as short as 45 days before calving. Low and high feed levels were variable, but animals on the low diets lost weight and those on high diets gained weight during the precalving feeding period. Results are shown in Table 6. The values represent the averages of the various traits from the seven studies. It is realized that problems can be encountered when summaries like this are made, but the results were very consistent.

Birth weight was increased, but the effect on incidence of dystocia was slightly in favor of the high gestation diets. Calf survival at birth did not differ but there was a 27 percentage point advantage in survival at weaning in calves from dams on the high precalving diets. The major reason for this survival difference was due to a much higher incidence and death rate from scours in the calves from the low-fed dams.

There was also marked carryover effects of the gestation diet on rebreeding of the dam. Breeding seasons ranged from 45 to 120 days duration. High feed levels resulted in more cows showing estrus by the beginning of the breeding season (+21%) and pregnancy rate (+10%). Precalving pelvic areas were determined in four of the studies, and there was a consistent positive effect (+15 cm^2) in favor of the high feed levels. A word of caution--these results do not mean that animals should be overfed during gestation. If they are and they become fat, the results will be drastically different. When the birth canal becomes filled with fat, more dystocia and calf deaths will occur at calving.

Table 5. Production of sires selected on birth weight EPD'S[a].

	Sire birth weight EPD	
	Moderate	High
No. calves	53	74
Gestation length (days)	282.6	282.5
Calf birth weight (lbs.)	68	85
Dystocia (%)	13	61
Calf losses (%)	5	8
Calf wean weight (lbs.)	397	419
Carcass data[b]		
Weight (lbs.)	576	674
% choice	90	68
Value/carcass ($)	536	627

[a] Data from first-calf heifers only.
[b] Feedlot data on steers only.

Maternal Effects. Dystocia studies presently underway at Miles City are designed to determine the effects of maternal environment on calf growth in the uterus and subsequent birth weight. Five maternal environments were studied involving F_1 heifers of 50% Brahman, Charolais, Jersey, Longhorn or Shorthorn breeding. The F_1 heifers were bred to one of two Angus bulls selected for either a moderate or high birth weight. This study was designed to determine fetal genotype X maternal environment interactions. The study was conducted in two parts; part 1 evaluated the calving and production performance of the F_1 dams, and part 2 involved slaughter of the F_1 dams at 231 days of gestation to determine fetal and placental growth. The calving and production phase is summarized in Table 7.

Shorthorn F_1 dams were the heaviest before calving and had the largest pelvic areas and highest calf birth weights. Jersey and Longhorn F_1 dams were the lightest precalving, had the smallest precalving pelvic areas and ranked next to the lowest for calf birth weights. Brahman F_1 dams ranked third for precalving body weight and pelvic area and lowest for calf birth weight. Calvings that required assistance were lowest in F_1 Brahman dams and highest in

F_1 Charolais dams. Gestation lengths were not greatly different among the breed groups but averaged shortest in F_1 Jersey and longest in F_1 Shorthorn dams. Calf weaning weights were heaviest in F_1 Brahman dams and lightest in F_1 Longhorn dams.

Table 6. Effects of gestation feed level on calving and subsequent reproduction.

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

[a] Averages from seven studies; cows and heifers combined.
[b] Diet level fed from up to 150 days precalving; low and high, animals lost or gained weight precalving, respectively.
[c] First-calf heifers only.

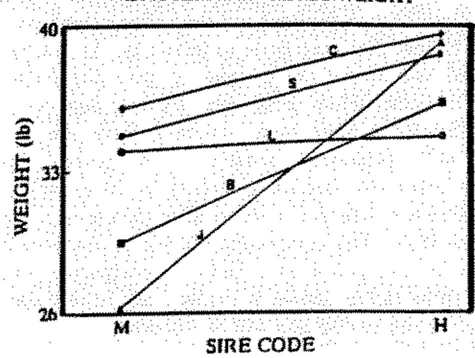
The second phase of this work involved slaughter of F_1 dams at 231 days of gestation. Dams had been bred to the moderate or high birth weight Angus sires, and detailed fetal and placental data were obtained as was carcass data on the dam. In interest of brevity eviscerated fetus weight will be the only trait discussed. Results are summarized in Figure 2, which shows eviscerated fetus weights of calves from the two sires within the five maternal environments.

The most striking difference is the growth of calves from the two sires in the F_1 Jersey maternal environment. Note also that the sire growth effect was approximately equal among the F_1 Charolais, Shorthorn and Brahman maternal environments, but the Brahman appeared to have the ability to suppress the overall growth potential of both sires. This, coupled with the 3% assisted birth rate (lowest) and the highest weaning weight (430 lb.) makes this a very interesting maternal influence. Figure 2 demonstrates a significant ($P<.05$) fetal genotype X maternal environment interaction. This can be summarized by stating that some maternal environments did not allow the fetus to express its genetic growth potential in utero while others appeared to complement it. This finding is of importance in helping us understand why some producers experience severe calving difficulty with some sires while others can use the same sires and have relatively few problems.

Summary

High calf birth weights are the main cause of dystocia. Pelvic area of the dam must be large enough to accomodate the calf. Selection for large pelvic areas in bulls and heifers will result in increased size of the entire skeleton and increased calf birth weights. Low feed levels during the last one-third of pregnancy will not result in predictable effects on dystocia but will be detrimental to all aspects of rebreeding of the dam. Significant fetal genotype X maternal environment effects have been shown. This resulted in some maternal environments not allowing the fetus to express its genetic growth potential in utero while other maternal environments appeared to complement it. These studies are helping with understanding factors that do and do not affect dystocia.

Figure 2. Fetal genotype X maternal environment effects.



Key: C, S, L, B, J = Charolais, Shorthorn, Longhorn, Brahman and Jersey F_1; M, H = moderate and high birth weight sire.

Table 7. Production of F_1 dams.

F_1 dam breed	No.	Precalving Body wt. (lb.)	Precalving Pelvic area (cm^1)	Calf birth wt. (lb.)	Assisted calvings (%)	Gestation length (d)	Calf wean wt. (lb.)
Brahman	20	955	260	68	3	283	430
Charolais	18	975	264	77	46	282	413
Jersey	31	864	243	71	22	281	417
Longhorn	22	833	252	71	17	283	353
Shorthorn	25	1,038	278	79	28	284	427
		$P<.01$	$P<.05$	$P<.01$	$P<.10$	$P<.05$	$P<.05$

MANAGEMENT OF COWS TO MINIMIZE POSTPARTUM INFERTILITY

R.E. Short, R.B. Staigmiller, R.A. Bellows, D.C. Adams and J.G. Berardinelli[10]

Introduction

Most beef production systems are based on an annual calving season with the length of this season being variable. More than one season of calving may exist within and between production units. In order for any system to be efficient and remain on an annual cycle, cows should rebreed within 82 days of calving (assuming a 283 day gestation period). Many factors work against that time line and cause a period of time during which cows are infertile. Several factors contribute to this infertility and result in reproductive losses and lowered production efficiency. The literature covering this topic is extensive. Therefore, this presentation is based on several recent review papers (Nett, 1987; Short and Adams, 1988; Bellows and Short, 1990; Odde, 1990; Randel, 1990; Short et al., 1990a; Williams, 1990). Please consult these reviews for a complete reference citation and coverage of data.

Factors affecting postpartum infertility

After parturition, cows are infertile for a variable period of time. Several factors contribute to that infertility. Illustrated in Figure 1 are: 1) the relationship between probability of a pregnancy occurring (infertility vs fertility) and time after calving and 2) the four main factors that contribute to infertility. In this figure the bold curved line shows the increase in potential fertility that occurs as time postpartum progresses. By forty days postpartum, potential fertility is quite high, assuming there are no severe problems with prolonged anestrus. A general infertility component exists that decreases fertility by 20 to 30% for any estrus regardless of whether it occurs after calving or at any other reproductive state. This component will not be discussed further, but it must be recognized as a factor in postpartum infertility. The other three factors shown in Figure 1 are related specifically to the postpartum period and will be discussed.

Uterine involution

Uterine involution has no relationship to length of the anestrous period. Nevertheless, uterine involution is a barrier to fertility during the early postpartum period. Fertilization rates and pregnancy rates are low in cows bred before 20 days after calving, but fertility returns to normal between 20 and 40 days after calving.

In several experiments, we bred cows which showed estrus very early after calving. Half of the cows were bred by normal AI procedures, and half were bred by surgically depositing semen into the tip of the uterine horns. Ova were recovered 3 days after insemination to determine fertilization rates. Inseminations into the tip of the uterine horn reduced the interval to conception by increasing the proportion of cows with fertilized ova when inseminations were done before 20 days after calving. Fertilization rates after 20 days were similar for both groups. We concluded that infertility during the first 20 days after calving is caused by a physical barrier to sperm transport and not by any inherent defect in the ova or other physiological mechanisms. We do not have data on whether an early postpartum uterus actually could maintain a pregnancy if a fertilized ovum were present. The noninvoluted uterus may not only be a physical barrier to sperm transport, but also it may be a barrier to implantation.

From a practical point of view, uterine involution usually is not a problem for beef cattle because it does not affect anestrus. Very few cows would exhibit estrus early enough after calving for uterine involution to interfere with conception so long as disease conditions do not prevent or delay normal involution. As discussed later, production systems with long breeding seasons are more likely to be affected by infertility related to uterine involution.

Short estrous cycles

Short estrous cycles also contribute to postpartum infertility during the first 30 to 40 d after calving. Most estrous cycles after 40 d are normal length. Ovulation following an estrus destined to start a short cycle are normal with ova released that can be fertilized. However, pregnancy usually does not occur apparently because the corpus luteum (CL) regresses before the ovary receives a signal from the uterus that a pregnancy exists.

Why is this first estrous cycle short? Is the CL not capable of functioning normally, or are regression signals being given prematurely? The CL formed during a short estrous cycle is smaller, secretes less progesterone (P_4) and is less responsive to stimulation. Gonadotropic stimulation of the short-cycle CL appears to be normal and not a limitation to its development, although follicle stimulating hormone concentrations may be low preceding this ovulation. The short-cycle CL is not hypersensitive to prostaglandin, nor is there any evidence of a problem with receptors or enzymes. So far, this evidence doesn't answer the question asked earlier; it merely reinforces the evidence that the short-cycle CL is functionally deficient.

Prostaglandin $F_{2\alpha}$ (PGF) appears to be the normal physiological signal whereby the uterus causes regression of the CL at the end of the estrous cycle. During the early postpartum period, high PGF concentrations probably prevents normal CL function because hysterectomy reduces PGF concentrations and allows normal CL function. The early postpartum uterus produces and metabolizes large amounts of PGF, and suppression or infusions of PGF further implicate a role of PGF in the control of CL function in the postpartum cow. Therefore, evidence exists to answer the question raised earlier. The functional capabilities of the early-postpartum CL are normal, but the CL is caused to regress prematurely by

[10] Authors are: Short, Staigmiller and Bellows are Research Physiologists with USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana. Adams is Range Nutritionist, University of Nebraska, West Central Research and Extension Center, Route 4 Box 46A, North Platte, Nebraska. Berardinelli, Dept. Animal and Range Science, Montana State University, Bozeman, MT 59717.

abnormally high PGF concentrations from the uterus. Regression occurs before the signal can be given that a pregnancy exists. These high PGF concentrations presumably are a part of the mechanisms involved in involution of the uterus. Uterine involution is involved with prevention of pregnancy, not only by blocking fertilization as described earlier, but also by preventing normal CL function.

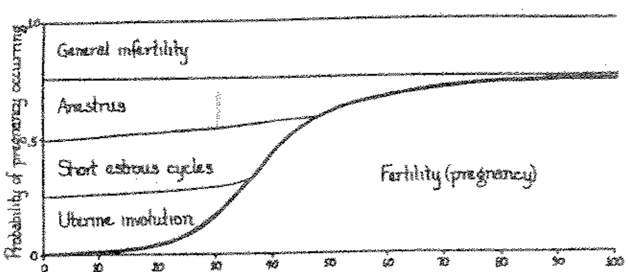
Normal CL function during an early postpartum estrous cycle can be obtained by pretreating with a progestin. The mechanism associated with the progestin effect involves a reduction in PGF with the effect mediated via the ovary rather than the pituitary. Some evidence exists for a luteinizing hormone-follicle involvement. Even ovarian or follicular involvements could be mediated indirectly through alteration in uterine endocrinology.

The short-estrous-cycle syndrome is a practical beef cattle problem because some cows exhibit estrus and are bred during the period that these estrous cycles occur, especially in more intensive operations where postpartum intervals are short and estrous synchronization is used. For early postpartum cows, estrous synchronizing treatments that include a progestin may have an advantage (Odde, 1989).

Postpartum anestrus

In beef production systems, postpartum anestrus can affect infertility for a long time (Figure 1); therefore, anestrus is a more serious problem than either uterine involution or short estrous cycles. Postpartum anestrus commonly is referred to as postpartum interval (PPI), the interval from parturition to first estrus. Intervals to other endpoints such as to ovulation or conception also are important, but from a practical point of view, estrus is the most logical measure of the commencement of potential fertility. Postpartum intervals will typically range from 35 to 70 d in reasonably managed beef cows. However, it is possible to have intervals as short as 10 to 20 d in well-nourished, nonsuckled cows and over 100 d in suckled, nutritionally stressed cows.

Figure 1. Relationship of fertility (probability of a pregnancy occurring) to time after calving. The factors contributing to infertility are shown above the fertility line.



Postpartum anestrus or post partum interval is affected by several minor factors: season, breed, age or parity, dystocia, presence of a bull, uterine palpation and carryover effects from the previous pregnancy as well as two major factors: suckling and nutrition. These factors all have direct effects and each factor can also interact with one or more of the other factors. Because of the many factors and interactions that affect postpartum interval, control and management of postpartum anestrus is complex.

Minor Factors

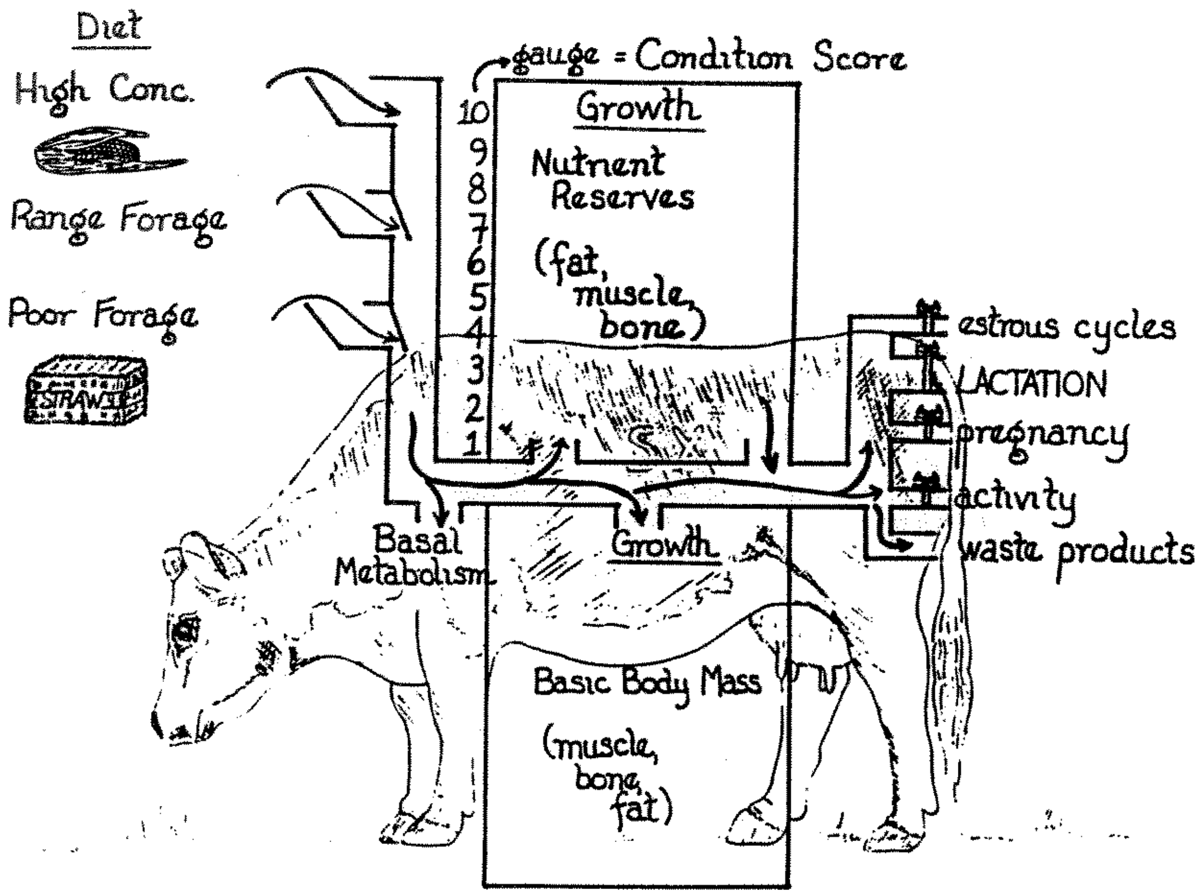
1. Season was one of the first factors to be associated with postpartum anestrus. Cows calving later in the spring had shorter postpartum intervals. In this case, day-of-year effects could be true season effects associated with light and temperature differences, or the effect could be confounded with nutritional changes as year progressed. Subsequent work has confirmed that day-of-year decreases postpartum interval as the spring calving season progresses and has shown that cows calving from late spring to early fall have shorter postpartum interval than cows calving from late fall to early spring. These seasonal effects are not due to nutritional and management differences but are true seasonal effects related to changes in light. However, seasonal effects are modified by nutrition and other factors such as genotype and suckling. From recent evidence, it appears that seasonal effects are mediated via the pineal. Injections of melatonin will increase postpartum interval. Not much can be done through management to correct seasonal effects on postpartum interval other than to shift the calving season.

2. Breed and genotype effects on postpartum anestrus can be seen by making comparisons between studies. Dairy breeds that are milked have shorter postpartum intervals than suckled beef breeds. However, when dairy cows are suckled, they have longer postpartum intervals than beef cows. Comparisons also have been made within studies which have shown that, when managed comparably, dairy genotypes have longer postpartum intervals than beef genotypes. These effects are more pronounced at first parity and on lower dietary intakes. Differences also have been reported between beef breeds with the effect being more pronounced at lower dietary intakes. How genotype affects postpartum interval is not known; effects may be due to true physiological differences among breeds, and(or) they may be due to confounding effects such as differences in amount of milk produced or appetite and feed intake. The effect of breed on postpartum interval is an important factor, and even though breed is usually predetermined, this effect must be accounted for when managing postpartum cows.

3. The effect of age and parity on postpartum interval is due mostly to the difference between 2- and 3-yr-old dams and older cows. Young cows have longer postpartum intervals and lower reproductive potential. Dystocia also is associated with age and will increase postpartum interval and delay rebreeding. The effects of age and parity cannot be eliminated, but the adverse effects of dystocia can be overcome, at least partially, by providing early obstetrical assistance.

4. Presence of a bull will decrease postpartum interval. The mechanism whereby presence of a bull accelerates the physiological processes that initiate resumption of estrous cycles is not understood. Available evidence implicates no involvement with either progesterone or luteinizing hormone. Putting sterile teaser

Figure 2. Partitioning of nutrients in a cow with nutrient intake varying in quality and quantity (from Short and Adams, 1988).



bulls with cows during the early postpartum period could be a useful tool in managing postpartum anestrus in beef cattle.

5. Postpartum reproduction also may be affected by other factors such as rectal palpation, treatment with a synthetic prostaglandin and effects of the calf. The effects of the calf apparently are related to differences in growth rate and amount of milk consumed; fast-growing, larger calves and (or) calves consuming more milk will have dams with longer postpartum intervals. These effects are more subtle or are fixed and are less likely to be manipulated by management. However, they should be considered when devising management strategies.

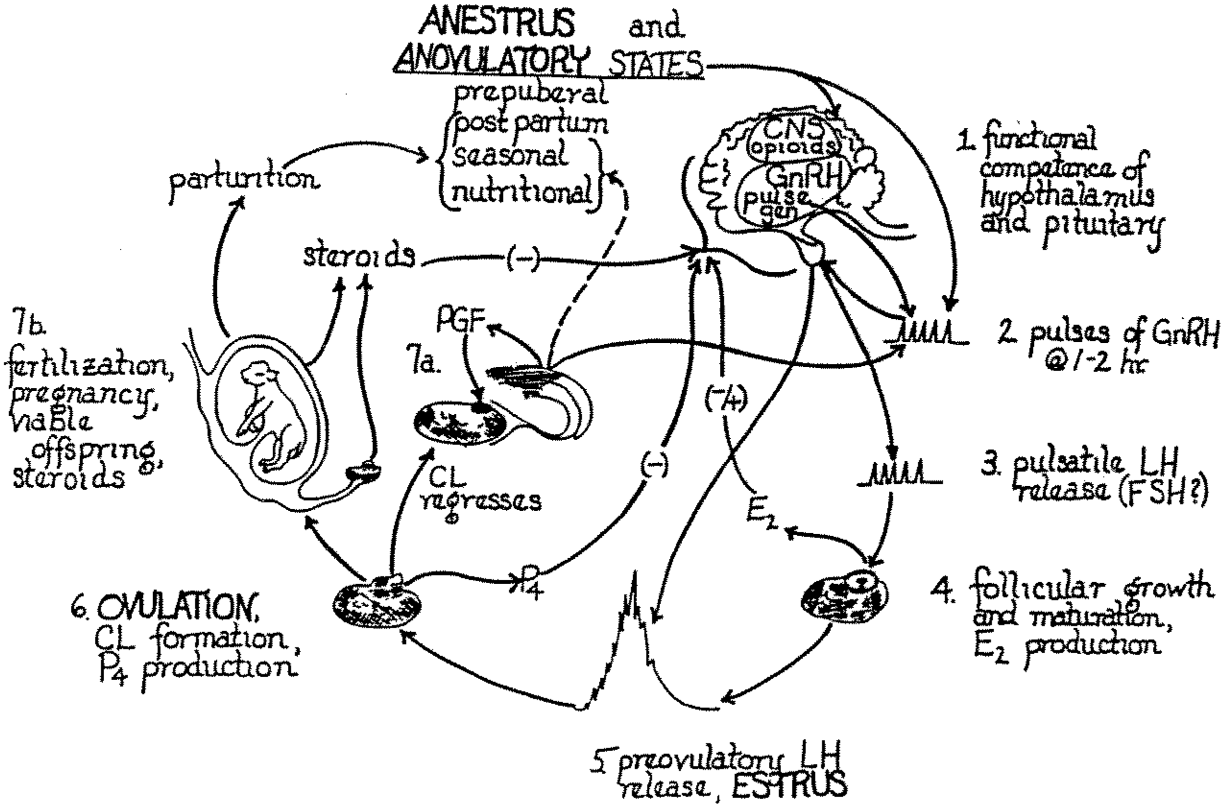
Major Factors

Suckling and nutrition are by far the most important factors determining the length of postpartum anestrus. Suckling probably has the most dramatic effect on postpartum interval and was one of the first factors to be related to postpartum reproduction. Cows that have their calves weaned at birth have shorter postpartum intervals than do cows that are suckled. If calves are weaned at some time after birth but before estrous cycles begin (usually between 20 and 40 days after calving), cows will return to estrus in a few days. Regulation of the suckling and lactation stimulus by weaning is a viable management option to decrease postpartum interval. Postpartum intervals can be decreased by complete weaning, short-term weaning (48 hours) or partial weaning (restricting suckling to short periods of time each day). However, response to weaning treatments will vary with other factors such as age, nutrition, genotype of the cow and age of the calf.

Nutritional effects are elicited via a complex interplay among many variables such as quantity and quality of feed intake, nutrient reserves stored in the body and competition for nutrients from other physiological functions besides reproduction. The effects of nutrition have been most commonly measured using energy as a variable. Other nutrients also may affect reproduction, but their effects are not well documented.

The allocation of nutrients to various body functions is commonly referred to as nutrient partitioning. A schematic representation of these relationships is shown in Figure 2. Illustrated in Figure 2

Figure 3. A model depicting the hormonal control of estrus and ovulation in postpartum cows (from Short et al., 1990a).



are several points about nutritional and production interrelationships. The first is that cattle (and other ruminants) have a unique niche in animal agriculture because they have the ability to convert low quality forages to useful products. The second is that excess nutrients can be stored during excess periods to be retrieved at a later time to maintain production. However, extended periods of limited nutrient availability because of low quantity and(or) poor quality will decrease production. The third is that nutrients are partitioned by a priority to first maintain life of the cow and then to propagate the species. The approximate order of priority for partitioning of nutrients is as follows:

1. Basal metabolism
2. Activity
3. Growth
4. Basic energy reserves
5. Pregnancy
6. Lactation
7. Additional energy reserves
8. Estrous cycles and initiation of pregnancy
9. Excess reserves

The relative priority of these functions can change depending on what functions are present and at what level.

Energy reserves can constitute almost 50% of an animal's maximum possible weight. One of the best ways of estimating nutrient reserves is the use of condition scores. As shown in Figure 3, estrous cycles usually can be maintained if condition score is 4 or greater although this may differ depending on other factors such as breed and whether an animal is entering into or coming out of anestrus.

The effect of nutrition on postpartum reproduction depends somewhat upon whether nutritional differences exist before or after calving. In general, the differences that exist at calving as estimated by precalving condition score are more important than those that exist after calving. These relationships are depicted in Figure 4. The effects of condition score at calving on postpartum interval are nonlinear with the effects being greatest at very low scores (<4), becoming less as condition score increases, with very little effect as condition score increases above 7. Postcalving dietary intake can alter these relationships, but postcalving differences in diets have their main effect when condition score at calving is <6 and when the feed intake is low vs adequate (100% of NRC) rather than adequate vs high.

Control mechanisms of postpartum anestrus

Control of the resumption of estrous cycles in the postpartum cow is accomplished by a complex relationship among the hypothalamus, pituitary and ovary which is impacted by a variety of external and internal signals. A major portion of this relationship is accomplished by hormone signals. A model for the hormonal control of estrus and ovulation is shown in Figure 3. Postpartum anestrus exists because the various factors discussed earlier prevent postpartum cows from proceeding through the normal steps (Steps 1 to 6, Figure 3) leading to estrus and ovulation. This series of events leading to estrus and ovulation is similar for postpartum cows and cows which are having estrous cycles. Somehow, the postpartum cow is prevented from continuing through these steps by one or more of the factors discussed earlier. We will now examine some evidence for how each of these steps is involved with postpartum anestrus.

The functional competence of the hypothalamus and pituitary is decreased for a 10- to 20-day period after calving. During this time, the amount of luctinizing hormone in the pituitary is lower, less LH is released in response to either estradiol (E_2) or GnRH, and the bioactivity of LH is lower. These differences do not seem to be related to suckling, pituitary LH content, hypothalamic GnRH content or pituitary GnRH receptors. However, these negative effects are not sustained and do not appear to account for the normal delay in resumption of estrous cycles observed in the suckled postpartum beef cow.

The primary defect that exists in the postpartum cow is a low serum concentration of LH caused by a low-frequency pulsatile secretion pattern of LH and presumably GnRH (Steps 2 and 3, Figure 3). During postpartum anestrus, the pulse pattern of LH typically is very low frequency (<1 pulse/4 hours). The frequency increases during the time preceding estrus to about one pulse every 1 to 2 hours. The GnRH "pulse generator" somehow must be inhibited during the early postpartum period.

A pulsatile pattern of LH release can be reproduced by giving low dose injections of GnRH every 1 to 2 hours. Postpartum cows treated in such a manner have shorter postpartum intervals. However, all cows do not respond to such treatment, especially if they are early in the postpartum period or on a low dietary intake. The inconsistency in the response to these treatments leads us to conclude that inhibition of the GnRH "pulse generator" is not the only cause of anestrus. The mechanisms for control of anestrus may be different depending on the cause (i.e., nutrition vs suckling), or the primary defect may change as the postpartum cow progresses from "deep" anestrus to "shallow" anestrus with time after calving. The amount of time required to make this transition varies with the amount of input from each of the controlling factors.

A pulsatile pattern of GnRH release may be only the strategy evolved to maintain a certain level of secretion because continuous infusions of GnRH will elicit a response similar to the pulse injections. Prolonged infusions of GnRH result in a decreased release of LH over time, but this decreased sensitivity to GnRH is not reflected by the endogenous pulsatile release of LH. At present there is no evidence to suggest that FSH is a limiting factor in postpartum anestrus.

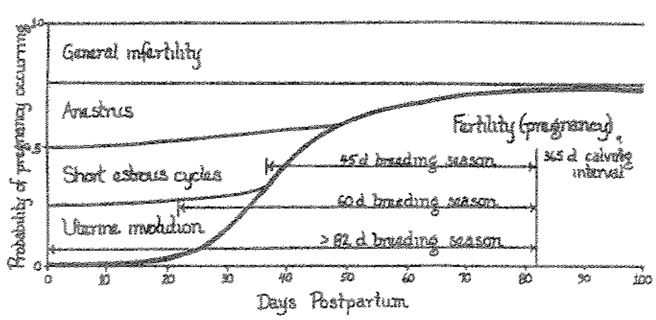
The ovarian component of anestrus (Step 4, Figure 3) is highly dependent on the status of the preceding steps, but in general the ovary per se does not seem to be a limiting factor because it will respond to exogenous stimulation. Follicular development and function are normal although there are some carryover effects of the CL of pregnancy. Follicles are selected from a pool of medium-sized follicles, and as follicles mature, they show an increase in number of LH receptors and switch from progesterone to E_2 production. Atresia is not related to gonadotropin binding. The main evidence for the ovary being involved in anestrus is that the pituitary-hypothalamus is hypersensitive to negative feedback of estrogen rather than an absence of the positive feedback mechanism discussed earlier.

This hypersensitivity to estrogen gradually is overcome to allow Steps 2 to 4 to proceed resulting in the continuation through preovulatory LH release, estrus and ovulation (Steps 5 and 6, Figure 3). Then the cycle repeats itself or pregnancy occurs (Steps 7a or 7b).

The stimuli that are detected by control mechanisms to retard or block the normal progression through these steps in Figure 3 are not understood, but several possibilities have been investigated. A role of the adrenal was implicated by some circumstantial evidence, but careful experimentation has ruled this out. Prolactin and oxytocin also were explored as a possible mediator but were ruled out. A direct neural involvement from the udder does not seem to be present.

The only positive evidence for a control pathway involves glucose and the endogenous opioid peptide (EOP) system. Even though evidence exists that the EOP system is involved in the control of LH release during the postpartum period, this system is only a part of the control system because prolonged treatment with an EOP antagonist only temporarily will release LH without subsequent ovulation.

Figure 4. Relationship of length of the breeding season to fertility during the postpartum period (from Short et al., 1990a).



Conclusions and management considerations

Postpartum infertility and anestrus are complex phenomena controlled by many factors, which may either act individually or in concert to decrease the production potential of beef cattle. Many of the factors that impact upon postpartum reproduction cannot be eliminated but can be included when making management decisions relative to other factors that can be manipulated. In making a management decision about postpartum anestrus, one must consider not only the potential benefits of a treatment on postpartum fertility but also the cost of implementing this treatment. For most production systems, maximum fertility will not be the most profitable. Optimum fertility rate for a given production unit will be that which returns the greatest profit (or some other defined measure of success) over a period of time. Unfortunately, only limited data are available on the costs of most treatments that affect postpartum fertility, so that aspect of the decision making process is left to the individual producer.

Nutrition

The most common problem encountered when prolonged postpartum intervals occur in a herd is poor nutrition at one or more stages of the production cycle. Resumption of estrous cycles after calving is a body function that has a fairly low priority compared to other functions such as lactation, activity, growth and basic body maintenance. The competition for and partitioning of nutrients in a cow was illustrated in Figure 3. Suckling greatly exaggerates the effects of poor nutrition, so nutritional and body reserve deficiencies are usually the first place to look when problems with postpartum anestrus are encountered.

Length of breeding season

Length of the breeding season has a very direct effect on whether postpartum anestrus is a potential problem. This relationship is illustrated in Figure 4 which was created by superimposing on the fertility graph from Figure 1 an illustration of the effects of the length of the breeding season. When cows are bred in a 45 day breeding season, they will be from 35 to 82 days postpartum at the beginning of the next breeding season, and most of them will have a high potential fertility at the beginning of the breeding season. As the length of the breeding season increases to 60 or 80 days, more cows are in the early postpartum period at the beginning of the next breeding season. When breeding seasons are longer than 80 days, some cows won't even have calved at the start of the next breeding season. Breeding seasons that are 45 days or less have several advantages that include weaning a larger, more uniform calf crop, but there also is an advantage in alleviating many of the problems due to anestrus.

Weaning

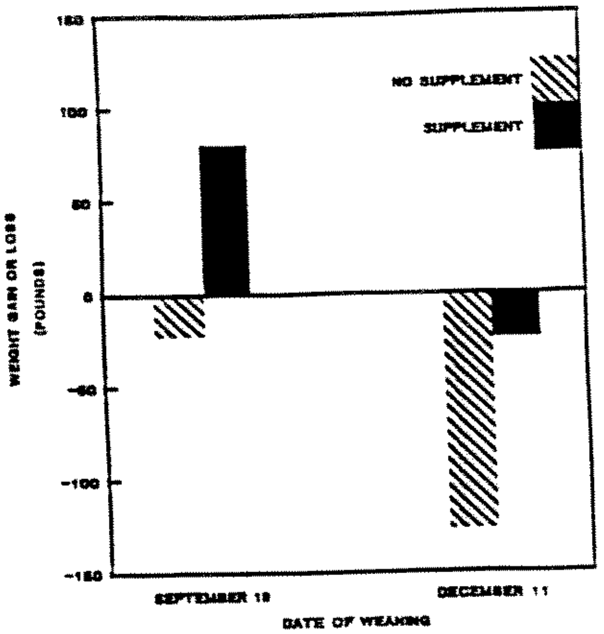
This option includes a wide array of possibilities from partial and temporary weaning to complete weaning and the weaning treatments can occur anywhere from right after calving up to 9 or 10 months after calving. In order for a weaning treatment to have an immediate effect on postpartum reproduction, it must occur before or early in the breeding season. Partial weaning is when calves are separated from their dams for most of the day and then are allowed one or two short periods during the day to suckle. Temporary weaning is when calves are completely removed from their dams for a short time (usually 2 to 4 days). Both temporary weaning and partial weaning can increase the number of cows that return to estrus during the breeding season. However, the response to these treatments is variable and management of these options is somewhat difficult. To maximize response of temporary weaning, the length of time calves and cows are separated needs to be longer than four days. However, prolonging the interval beyond four days will potentially decrease milk production and weaning weights. Until more is known about the causes of variation in response and how to manage correctly, temporary and partial weaning have limited practical applications.

If prolonged anestrus is a problem in a herd, then a more sure short-term solution may be complete weaning shortly before the beginning of the breeding season. Assuming that body condition scores are reasonable (≥4 on a scale of 1=thinnest to 10=fattest) and most calves are over 20 days old, then most cows that are anestrus will return to estrus in 4 to 10 days. This treatment can be quite effective in inducing and synchronizing estrus in anestrus cows, and the early weaned calves can be successfully reared on a forage (grazed or harvested) and concentrate diet. However, this option has more severe economic limitations and must be carefully evaluated before implementing.

The weaning options that have the most practical application in the long run and will affect postpartum anestrus have to do with the age of calf at normal weaning. Most cow-calf operations wean their calves somewhere around six or seven months of age, but it would not be uncommon to delay weaning to 8 or 10 months. Manipulating age at weaning in the range of 6 to 10 months will have no immediate effect on anestrus and rebreeding because if cows are calving on an annual basis, the breeding season should already have passed. The potential benefits of altering age at weaning at this stage will not be realized until the next breeding season. The primary objective to consider at this point is body condition at calving time the next year. Cows that calve in late winter or early spring are normally wintered in situations where quantity and quality of feed (mainly forage) is low, and the cows often are subjected to environmental stress (cold temperatures). This limited availability of feed and cold stress makes it hard to recover from body condition scores that are too low going into the winter.

Data from a recent study at LARRL in Miles City illustrate how changing weaning age can affect body weight and condition score. Forty-eight cows that calved in April were assigned at random to have their calves weaned on either September 19 or December 11. Half of the cows in each weaning age treatment received .75 lb. of supplemental protein per day and half received no supplement. All cows grazed on native range forage during the study. Changes in body weight (Figure 5) and condition score (Figure 6) were quite dramatic. The losses induced by late weaning were almost completely prevented by protein supplementation, and supplementing the normal weaning age cows resulted in marked improvements. We conclude from these data that even though supplementing during this time is unusual, it can prevent problems created by late weaning. However, if cows are going into the fall in poor condition, it would not be wise to wean late even with supplementation. If cows are thin enough to require an increase in condition score, then supplemental protein along with weaning at five to six months of age can help cows recover. Supplemental protein will only work if sufficient energy is available from grazed forage.

Figure 5. Weight changes of cows from September 19 to December 11 when calves were weaned either on September 19 or December 11. Half of the cows on each weaning treatment received no supplement and half received .75 pounds per day of supplemental protein.

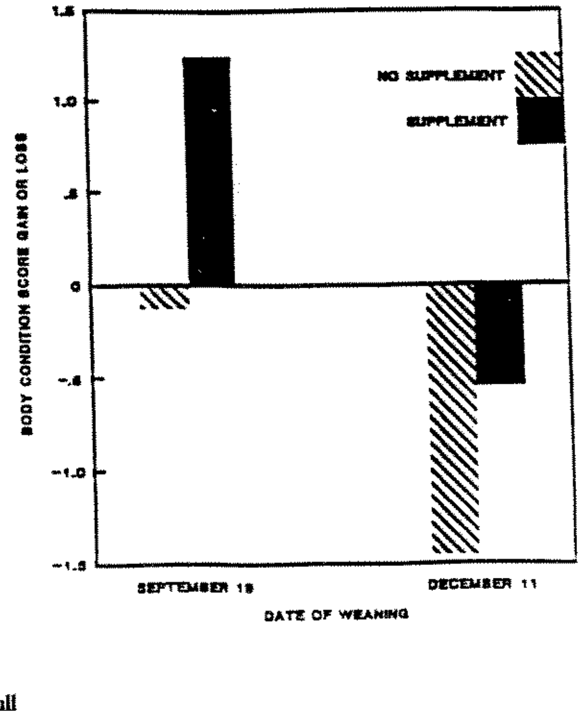


Most work with manipulating suckling effects has been done with spring calving cows. Very little work has been done with fall calving cows which is a management practice that is becoming more common in some regions. Fall calving has advantages, but a real problem is that the peak demand for nutrients that occurs during lactation is out of synchrony with peak nutrient availability from forage. Therefore, fall calving cows may respond differently to different weaning treatments. We have a fall calving herd that is a contemporary to the spring calving herd used in the study covered previously. The fall herd is weaned either before the breeding season (~60 days postpartum) or at six months postpartum. This is the first year of this study, and the early weaned cows had a 50% pregnancy rate after a 30-day breeding season compared to only 16% for the cows that will be weaned at 6 months. If fall calving cows are not early weaned, then late weaning may be more appropriate since there will be a greater amount and quality of forage available for them at this time than spring calving cows. Experiments need to be done to test that possibility.

Estrous synchronization

Synchronization of estrus is a useful tool for shortening the breeding season, concentrating labor and making the use of artifical insemination more feasible for beef cattle. A secondary benefit is realized in postpartum cows when synchronization treatments include the use of progesterone or a progestin. Progestins in the synchronization treatment will induce some cows that are anestrus to start estrous cycles. Therefore, if many of the cows in the herd are anestrus, then a higher percentage of cows will be bred in treatments that include a progestin. Progestin treatments should not exceed 10 to 12 days for maximum fertility. If treatments are to be longer than that, they should be given as a pretreatment with breeding occurring at the second posttreatment estrus. The best treatment was feeding melengesterol acetate (MGA) for 14 days with an injection of a prostaglandin 16 to 18 days after the last MGA feeding. Cows are detected for estrus after injection of prostaglandin and bred by AI. Conception rates of 60 to 80% are obtained with this treatment. A disadvantage of this treatment is that it is long and difficult to use if calving seasons are greater than 50 days.

Figure 6. Changes in body condition score of cows shown in Figure 4.



Bull

Presence of a bull during the postpartum period will decrease the interval to first estrus. The mechanisms involved with this effect are not known, but it may be advantageous to use a sterile teaser bull to run with postpartum cows before the breeding season starts to stimulate resumption of estrous cycles earlier. Care should be used in selecting these teaser bulls to insure that they are sound and free of disease. Information is needed to understand more about the situations in which this treatment will work, how beneficial it is and how response can be maximized (i.e., what is the best cow:bull ratio?).

Dystocia

Cows that have dystocia (calving difficulty) have longer postpartum intervals. Management systems which minimize dystocia will not only save more calves but will also have higher rebreeding rates of the cows the next breeding season.

Summary

Anestrus is one of the major problems with low potential fertility in beef cattle. Suckling and poor nutrition are the main causes of anestrus. Solving nutritional problems can partially overcome inhibitory effects of suckling, but other management decisions can also reduce the negative effects of suckling induced anestrus. Shortening breeding seasons to ≤45 days, using appropriate weaning times, synchronizing estrus with a treatment that includes a progestin, using a teaser bull before the breeding season and minimizing dystocia are all management options which can decrease the effects of anestrus. The decision of whether to include any of these options should include an assessment of the value of the increased production potential in relationship to the anticipated cost of implementing these practices.

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MANIPULATING EMBRYOS: NEW APPROACHES TO "REAL WORLD" QUESTIONS

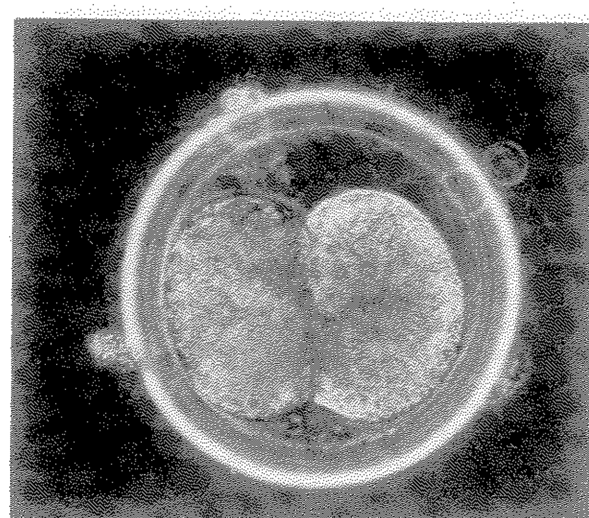
R.B. Staigmiller, R.A. Bellows and R.E. Short[11]

Introduction

When we look at a healthy newborn calf it is hard to imagine that some 284 days earlier it was a very simple 2 cell structure (see Figure 1) about the size of the point of a pin, yet containing all the genetic potential of a full grown animal. The embryo is very fragile during this early period of time, but it also holds tremendous potential for usefulness to the beef cattle industry. Our interest in studying early embryos is based on four different aspects of their importance to beef cattle production: 1) embryo mortality during early pregnancy; 2) use of embryo transfers as a production alternative; 3) use of embryos as a research tool; and 4) use of embryos for genetic enhancement. Lets look at each of these factors in detail.

[11] Authors are Research Physiologists from USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana.

Figure 1. Two cell embryo.



Embryo Mortality. Loss of an embryo during the first 20 to 25 days of pregnancy is often not recognized for what it is. When an embryo dies at this stage of pregnancy the cow will cycle again after only a few days delay. Hence, she may show a slightly longer cycle which can easily be seen as a conception problem rather than embryo mortality, if it is recognized at all. At best this will result in the cow being delayed in getting pregnant, and at worst it may result in the cow remaining open. Early embryo mortality may be indicative of disease problems such as vibriosis, and there are obvious advantages of detecting this early.

But apart from disease conditions, early embryo mortality can also be indicative of other problems. Embryo mortality can result from conditions occurring at fertilization. If the ovulated egg must reside too long in the reproductive tract before the semen is deposited this aging egg may fertilize but death often occurs during early embryo development. In this case, our breeding management, particularly in artificial insemination programs, may need to be fine tuned.

Also, Dr. Short and Dr. Bellows demonstrated very clearly right here at Miles City that embryo mortality can result from undernutrition. Changes in the oviduct and uterus are occurring on a daily basis during early pregnancy and in underfed cows the capability for the appropriate changes are limited. As we gain more and more understanding of the fertilization process and the relationship between the embryo and the reproductive tract, we should be able to manage our breeding herds in a manner to decrease embryo mortality and increase our net calf crop.

Embryo Transfer. The use of embryo transfer in the beef industry has increased by leaps and bounds during the last 10 to 15 years. It has been used most commonly in the seed stock industry as a means of increasing the number of offspring from superior females. In this procedure, selected females are treated with hormones that cause them to ovulate multiple eggs. They are bred to selected males and when the embryos are 7 to 8 days old they are recovered nonsurgically through a rubber tube inserted into the uterus in a manner similar to that used for depositing semen during artificial insemination. Once recovered the embryos are transferred to recipient females, or frozen until appropriate female recipients can be obtained. Some highly successful cows have produced more than 60 living offspring over a five year period using these techniques. While such performance is certainly more the exception than the rule, it does demonstrate the contribution that can be made by this technology.

The embryo transfer technology is also useful as a means of importing cattle. The cost associated with importing frozen embryos is only a token of that needed to bring cattle into this country and go through the necessary quarantine. Very strict measures are necessary to guard against transferring disease along with the embryos, however, and embryos must meet certain specifications to insure that they are disease free. But imagine the extent to which embryo transfer could have been used if it was available in the 60's and 70's when the so called "exotics" were in demand and being imported from all around the world.

The full extent to which embryo transfer will find its place in the cattle industry is yet to be decided. Artificial insemination is now the major means of breeding dairy cattle but represents only a small percentage of the beef cattle bred in this country. Embryo transfer is not likely to be greatly different. Like AI, embryo transfer requires intensive management, and is also quite labor intensive. There are, however, some distinct advantages and disadvantages of embryo transfer when compared to AI. It is an advantage to be able to select the genetics of both the dam and the sire, as opposed to just the sire in the case of AI. By selecting superior producing animals for both, the rate of genetic progress can be speeded up. Another advantage is that the timing of the transfer is not as critical as it is in AI. There is a 24 to 36 hour time span for transfer that will yield optimum conception, as opposed to about 8 to 12 hours for AI. Transfer is performed 7 or 8 days after the recipient female has been detected in heat so the scheduling of transfers can be done well in advance. On the side of the disadvantages, an embryo is more expensive to generate than is a dose of semen. The technology for producing large numbers of embryos inexpensively is still a ways off, and costs will have to be reduced considerably before embryo transfer can be used to its fullest potential in the beef industry. Also, the best conception rates with embryo transfer are 5 to 10 percent lower than they are for AI. This is improving continually, however, and probably will not be a serious problem in future years.

Certainly embryo transfer will not be applicable to all, or even a majority of beef cattle operations. It will obviously have very limited application in the western rangelands where very large pastures and free ranging livestock represent the major means of production. While the full potential of embryo transfer awaits continued improvements in technology, the contributions being made at the present are valuable and we can expect this new technology to continue to play an important role in the beef industry.

Research. Embryos and the embryo transfer technology are being used as research tools to provide information that was unattainable without these techniques. Our work on two specific projects here at Miles City can demonstrate its usefulness.

We have shown that replacement heifers bred at their first estrus (puberty) are not as likely to conceive as they are when bred at a later estrus. We would like to know if the reduced conception is due to the oviduct and uterine environment not being adequately developed, or alternatively if the first egg that the female ovulates is of poor quality and not capable of fertilization and development. We can answer that question by transferring embryos from mature cows into heifers at the first estrus or at a later estrus. If the conception rate is the same, we will know that the uterus is fully capable and the problem must be with the embryo. This question could not be answered without the capability of using embryos unrelated to the heifers being bred.

In a second example, Dr. Bellows has shown that size of the calf at birth is dependent on the breed of the dam. That is, calves sired by the same bull will be heavier at birth when bred to Hereford dams than Brahman dams. This differential growth rate of the fetus may be due to the genetic contribution it received from the dam, or it may be due to the uterine environment of the dam. To determine which of these two possibilities is the cause it is necessary to separate the breed of the dam from the breed of the calf. This can only be accomplished by obtaining embryos whose genetics are totally unrelated to that of the female that will carry the offspring through pregnancy. Embryo transfer provides the means of doing these studies.

These are just two examples of how embryos are being used here at Miles City, but there are many more opportunities for their use. Embryos can be split in half with each half being transferred to separate females to yield identical twins. By multiple splitting as many as 5 identical offspring have been born. Since identical offspring perform more alike than unrelated offspring they are valuable to research for determining differences between treatments.

At Fort Keogh we are now trying to generate embryos entirely in the laboratory. By starting with just an ovary we can extract the eggs and over the next 8 days will fertilize them and culture them in an incubator as they grow from a 1-celled egg to an embryo equivalent to those recovered at day 7 of pregnancy. This gives us the opportunity to study every aspect of embryo biology from before conception to a day 7 embryo and to determine more precisely what the oviduct and uterus must provide for the new offspring.

Genetic Enhancement. Embryos also provide us with yet another important capability. In the last few years advances in genetic engineering and gene transfer, have provided the capability to transfer desirable genes into newly conceived embryos. Genes are injected shortly after the egg is fertilized so being able to fertilize them in the laboratory is a great advantage over recovering them surgically from the cow after mating and fertilization has occurred.

Perhaps it is worth looking at some of the potentials and some of the limitations of genetic engineering and gene transfer. First of all, this technology really does not do anything different than what ranchers have tried to do for years, namely, select animals that contain the type of genes desired in the offspring. When normal selection procedures are used, however, we must take a wide variety of genes that accompany the ones we want in an animal. With gene injection we can select specific individual genes to be incorporated into the herd. The most difficult part of the procedure is identifying the gene for the trait desired, and isolating it in a form that can be injected. This is the work of the genetic engineers.

One of the limitations of this new technology is that many of the traits we would like to see developed in our herd are not controlled by just a single gene. Growth for instance, is controlled by many genes. We can inject a single gene that will increase the rate of growth but it results in animals that are not sound because all the factors that contribute to growth are not in balance. On the other hand, the immune system has the potential to respond quite well to this new technology. An antibody produced by the immune system to fight a specific disease is produced in the body by the action of a single gene. It is not unthinkable that in the future we may be able to develop animals with increased resistance to specific diseases by changing the immune system through gene injection. Imagine the savings each year to the beef industry if we could enhance the response of the immune system to scours and cut calf losses to that disease by as little as even 15 to 20 percent.

Conclusions

In summary, the stage of early embryo development is critical in the life of the newly conceived calf. Embryo transfer continues to make sound contributions to animal agriculture through the ability to increase the number of offspring from superior females, as well as serving as a valuable tool for answering important questions through research in beef production. Furthermore, early embryos provide the means of making some dramatic and important changes in the genetic makeup of our future cow herds.

PINE NEEDLE ABORTION UPDATE

R.E. Short, R.B. Staigmiller, D.C. Adams, R A. Bellows,
S.P. Ford, L.K. Christianson, K.E. Panter,
J.A. Pfister and L.F. James[11]

Introduction

Abortions can occur in cattle after consumption of needles from Ponderosa pine trees (McDonald, 1952; James et al.,1989). Significant economic losses are caused by pine needle induced abortions in the western United States (Lacey et al., 1988). Adjustments must be made in range management to alleviate the problem (Gartner et al., 1988). The term abortion is not technically correct since the fetuses are usually alive at birth (James et al., 1989). Even though not technically correct, we will use abortion in this paper when referring to the effects of pine needles since it is such a commonly used term to describe this effect. We know very little about how or why these abortions occur. The effect appears to be pharmacological rather than pathological (Stuart et al., 1989), green needles work as well as dried ones (Jensen et al., 1989), and there is evidence that the hormones responsible for maintaining pregnancy have abnormal secretory patterns in cows that have eaten pine needles (Short et al., 1989). Several experiments with pine needles have been conducted since our last field day report (Short et al., 1987) and will be presented.

Experimental Procedures

Pregnant cows at a known stage of pregnancy were fed a given amount of pine needles. Pine needles were collected by cutting down Ponderosa pine trees and either stripping off needles directly or cutting off branches to have needles stripped off at a later time. The branches and needles were then transported to the laboratory where they were air dried and stored until used. Air dried needles were ground through a one inch screen hammermill and were fed

[12] Authors are: Short, Staigmiller and Bellows are Research Physiologists from Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana. Adams is Range Nutritionist, University of Nebraska. Ford and Christianson are from Iowa State University, Ames, Iowa. Panter, Pfister and James are from USDA-ARS Poisonous Plant Research Laboratory, Logan Utah.

to cows at a specified rate mixed with ground hay. In the following studies the effect of pine needles on pregnancy maintenance is estimated by the interval to calving which is the number of days from the beginning of pine needle feeding to calving

Experiment 1. Little is known about the mechanisms regulating consumption of pine needles by cows or the response to pine needles after they are consumed. Providing increased levels of nutrients, alternative forages or additional forages for fill may alleviate or decrease either consumption of or response to pine needles.

Trial A. Thirty-two pregnant crossbred cows were placed on experiment at 250 days of pregnancy to study the effects of protein level of the diet and availability of straw on consumption of Ponderosa pine needles (PN) and abortion response to PN.

Isocaloric diets were fed that were either high (HP=1020 g/d) or adequate (AP=710 g/d) for protein requirements. Dietary protein was increased for HP cows by partially substituting soybean meal supplement (SB) for alfalfa hay (AH). Coarse-ground wheat straw (S) was either not fed or fed ad libitum. Dried, coarse-ground PN were fed ad libitum to all cows. The base diet, S and PN were each fed in a separate container. Cows were paired by weight and breeding date and each pair was penned separately during the trial. Four pairs were assigned to each of the 4 treatments. Feed consumption was measured by pair but is reported on a per cow basis. Feed intake and calving data are shown in Table 1.

Table 1. Effect of amount of dietary protein and availability of straw on consumption of pine needles and parturition response.

	Amount/day (lb)				days to calving	
Treatment	AH	SB	S	PN	ave.	range
AP	25	0	0	1.6	12.5	8-19
AP+S	25	0	3	1.3	13.4	5-20
HP	18	4	0	2.9	11.5	5-20
HP+S	18	4	2.5	2.2	11.8	4-19

The interval to calving for control cows fed the AP ration but no PN was 33.9 days. All cows with access to PN did abort. The consumption of PN was highly variable in amount and when consumed. No significant differences were observed for amount of PN consumed or for interval to abortion. Our conclusions are that these data do not provide any evidence that protein content of the diet or availability of straw will affect consumption of PN or abortion response after consuming PN.

Trial B. Forty pregnant cows were assigned at random to one of five treatment groups to study the effect that weathering of needles, feeding a mineral supplement or feeding corn silage rather than hay have on response to feeding pine needles and to determine whether abortions continue after feeding pine needles is discontinued. The five treatments were: 1. Control, fed 18 lb. of hay. 2. Hay + pine needles (PN), cows were fed 13.5 lb. of hay and 4.5 lb. of pine needles per day until 50% had aborted. 3. PN + magnesium supplement (PN-Mg), diet as in treatment 2 with the addition of 20 g. of a magnesium supplement per day. 4. Silage + PN (SPN), ration the same as in 2 except that corn silage was substituted for hay on an equivalent energy basis. 5. Hay + weathered pine needles (WPN), the ration was as in treatment 2 except that the pine needles were allowed to weather for 12 months at the site of collection on trees that had been cut; processing was then as usual. The base rations were started 4 weeks before the beginning of PN feeding which started at 250 days of pregnancy. Pine needles were fed for 7 days which was the point at which 50% of treatment 2 cows had aborted. Results are summarized in Table 2.

Table 2. Effect of diet on interval (days) to calving and proportion of cows aborting (number of cows in each category shown in parentheses).

	Treatment				
Aborted	Control	PN	PN-Mg	SPN	WPN
no	37.3(11)	39.0(4)	34.0(3)	---(0)	---(0)
yes	---(0)	6.8(4)	7.0(5)	8.3(7)	5.8(6)

Pine needle feeding caused abortion in 50% of the cows after only seven days of feeding, and the cows that did not abort had a normal gestation length. Feeding a magnesium supplement had no effect on the response, while either feeding silage instead of hay or weathered needles instead of nonweathered seemed to accentuate the response.

Experiment 2. Four trials were conducted to determine effects of feeding a progestin (melengesterol acetate, MGA), corn (C) or a prostaglandin inhibitor (ketoprofen, KP) on abortions caused by feeding Ponderosa pine needles (PN) during late pregnancy. PN were air dried, ground and fed (6 lb. per day) with an equal amount of hay for 21 (Trials 1 & 2) or 8 (Trials 3 & 4) days or until parturition. Trial 1: 48 cows were assigned to 1 of 6 treatments at 250 days of pregnancy. MGA was fed during the PN feeding period but started 1 day before PN and was fed mixed with 4 lb. of ground C at the rate of 0, .5, 2 or 4 mg per day. Trial 2: 54 cows at 240 days of pregnancy were assigned to 1 of 6 treatments to study the effects of feeding MGA on pine needle abortion. MGA was either not fed (0MGA) or fed (4 mg per day) either from day 240 to the end of PN feeding (short MGA, SMGA) or to day 280 (long MGA, LMGA). 65% of LMGA calves were born dead. Trial 3: 12 cows were fed PN at 250 days of pregnancy with half being fed no corn (0C) and half fed 4 lb. of corn per day (C). Trial 4: 15 cows at 260 days of pregnancy were assigned to 1 of 3 treatments. KP was fed (4 g) 2 times daily during PN feeding. Intervals to parturition from the first day of PN feeding are shown in Table 3.

Our conclusions were that pine needles caused a premature parturition which was delayed by MGA or ketoprofen but continued feeding of MGA resulted in a high death loss of calves, that corn did not delay the response to pine needles and that pine needles induced parturition by causing an interruption in the progesterone maintenance mechanism through a prostaglandin pathway.

Table 3. Effect of feeding MGA, corn (C) or a prostaglandin inhibitor (KP) on interval (days) to calving.

PN	Amount of MGA, Trial 1*				length of MGA feeding, Trial 2*			Trial 3		Trial 4*	
fed	0	.5	2	4	0	S	L	0C	C	0KP	KP
no	35.0			31.9	43.9	36.7	42.0			24.0	
yes	14.4	15.5	19.0	22.5	26.7	24.1	41.1	5.3	9.3	7.2	17.5

Experiment 3. This experiment was conducted to determine if ground needles would lose their abortifacient activity if they were left exposed to air for several months and whether feeding bentonite or a mineral supplement will prevent abortions. The experiment is outlined in Table 4. A portion of the pine needles were ground the previous summer, spread out on a concrete floor and left exposed until being fed in March. The remainder of the needles were not ground until within a week of being fed. Bentonite is commonly used in cattle diets as a binder, filler or nutritional enhancer, but it also has unique chemical properties that allow it to bind organic molecules. If it would happen to bind the chemical that causes abortions then it would be useful to prevent abortions. The magnesium supplement tried earlier did not prevent abortions so this time a more complete mineral supplement was used to determine if it would prevent abortions. Needles were fed for two weeks or until abortion occurred. The mineral supplement was fed starting 60 days before the experiment started, and the bentonite was started 7 days early. Leaving ground pine needles exposed to air for several months did not diminish their ability to induce abortions, and neither bentonite nor mineral supplement affected the abortion response to pine needles.

Experiment 4. Very little is known what effects pine needles have in the rumen so a digestion trial was run with lambs to determine the effects that pine needles have on both in vitro and in vivo digestibility. Crested wheatgrass was used as the base diet, and then pine needles were fed in increasing percentages of the diet. In vitro organic matter digestibility decreased as percentage of pine needles increased in the substrate. The main decrease occurred as percent PN went from 0 to 40% (IVOMD decreased from 55 down to 30%). Effects of pine needles in lambs is shown in Table 5.

Digestibility of dry matter, organic matter and fiber decreased somewhat uniformly throughout the range of %PN in the diet. Protein effects as measured by digestibility, formation of urea nitrogen and nitrogen retention also decreased as %PN increased, but there were very dramatic changes at the 50% level. Pine needles have very marked effects on digestion but it is not known whether these changes have any relationship to the effects of pine needles on abortion.

Cooperative studies with Iowa State University. Recently we have started some cooperative work with Dr. Steve Ford at Iowa State University. He and his associates have been studying blood flow and hormone metabolism during late pregnancy in cattle. The laboratory and animal models they are using in these studies appear to be ideal for studying the physiological mechanisms in pine needle abortion. Results of the first study with them on pine needle abortion have been quite exciting (Christianson et al., 1989). They found that plasma collected from pregnant cows fed pine needles drastically reduced blood flow in a laboratory perfusion test as compared to no effect for plasma from cows not fed pine needles. The laboratory test is conducted by dissecting a complete fetal and maternal placentome (cotyledon) from a uterus obtained from a cow in late pregnancy at slaughter. The placentome is placed in a perfusion chamber so that fluid can be pumped independently through arteries on the fetal and maternal side and effluent collected from veins after the fluid passes through the placentome tissue. The pressure and amount of fluid pumped through the tissue is used to estimate blood flow. This in vitro system is now being used to assay pine needles to identify the active agent. Dr. Jack Rosazza at the University of Iowa is using different extraction and isolation techniques to separate components which are then assayed in the in vitro system. They are now in the third phase of the isolation procedure.

Dr. Ford's laboratory also has the capability of monitoring blood flow and endocrine activity of the uterus during pregnancy in cows. A group of cows and dried pine needles were sent to Ames last winter for them to conduct an experiment to determine the effects of pine needle feeding on blood flow and hormone production in the uterus. All cows were fitted surgically with appropriate cannulae and flow monitors on day 240 of pregnancy. On day 250 half were fed 6 lb of pine needles and 12 lb of hay per day. The other half

Table 4. Effect of diet variables on abortion response.

Treatment	no. cows	amount fed (lb) hay	corn	PN	bent	suppl	no. aborted	days to calving aborted	normal
control	7	16	2				0	--	34.6
PN	8	12	2	4.5			5	5.4	39.7
ground PN	7	12	2	4.5			7	6.3	--
PN+bentonite	8	12	2	4.5	2		8	6.5	--
PN+mineral	8	12	2	4.5		2 oz	8	5.6	--

Table 5. Effects of pine needles on digestibility(%) of diet components in lambs.

Trait	% PN in the diet 0	12	25	50
Dry matter	59	51	51	42
Organic matter	61	53	52	44
Neutral fiber	59	49	44	31
Acid fiber	52	40	37	24
Protein	44	23	31	4
Urea N	2.8	2.5	2.3	8.4
N retention	-.1	-1.3	-1.0	-7.7

served as controls and were continued on straight hay (18 lb/day). Blood flow decreased markedly after the start of pine needle feeding and decreased to 30% of control values by five days after feeding started. There was no evidence that uterine production of steroids was altered except in one cow which did not abort. In that cow peripheral progesterone concentrations initially decreased but then rebounded as the uterus started production of progesterone. Pine needle feeding was discontinued to her after two weeks, and she calved normally. This experiment confirms the effect of pine needles on blood flow to the uterus shown in the in vitro study above. The mechanism involved in pine needle abortion appears to involve an interference with blood flow to the uterus with the subsequent stress to the calf causing the signal for parturition to start to be initiated by the calf.

Conclusions

Results from these experiments and those reviewed earlier provide us with useful clues in unravelling the pine needle abortion puzzle. Unfortunately, we have not progressed to the point of having a practical solution to prevent these abortions (other than making sure cows don't have access to needles). On the bright side though, the results from these studies have brought us to the point where we are starting to understand pine needle abortion. We are started on a research path that should resolve this problem.

Our conclusions from these studies are:

1. No evidence was found that mineral supplements, bentonite, aging ground needles, varying protein content of the diet, providing straw free choice or feeding silage instead of hay will prevent abortions caused by pine needles.

2. Feeding a synthetic progestin (MGA) or a prostaglandin inhibitor (ketoprofen) will delay or prevent abortions but these compounds probably are only useful for determining physiological effects and not as a practical solution.

3. The effect of pine needles is to decrease blood flow to the uterus so that the resulting stress to the fetus causes a signal to be given by the fetus for parturition to start. This finding is useful in understanding the mechanism and provides an assay for the active ingredient in the pine needles.

4. Until we have a better understanding of the mechanisms involved with pine needle abortion and can develop appropriate treatments to prevent these abortions, management of pregnant cows on ranches with a history of pine needle abortion should follow grazing management recommendations outlined by Gartner et al. (1988). Management practices to prevent pine needle abortions may include appropriate use of fencing, early grazing of pastures with pine trees, clear cutting or selective cutting and trimming of lower branches.

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THE POTENTIAL FOR GENETIC TECHNOLOGY: DEVELOPING BREEDING OBJECTIVES

Scott Newman and R.W. Ponzoni[13]

Introduction

Rather large potential responses to selection for weights at various ages has encouraged cattle selection programs that are based almost exclusively on weight and weight gain. Bio-economically important characters such as reproduction and maternal characters as well as correlated characters, some of which are deleterious (e.g., increased cow maintenance costs) have been neglected. There is not a single "best" breeding program to improve beef production in the United States today. Tailoring breeding programs for specific resources and markets, but, at the same time, making them comprehensive to overall industry needs, is essential.

Developing a breeding program can be looked upon as a sequential procedure. An example of this would be (1) define a breeding objective; (2) choose appropriate selection criteria; (3) organize a performance recording scheme; (4) use performance information for making selection decisions; (5) use the selected animals. Notice that development of the breeding objective is the first step of the procedure, and is therefore crucial. Failure or inadequacy in defining a proper objective could result in genetic change in an undesirable direction.

The breeding objective can be defined as the combination of economically important traits of beef cattle in the production system. Breeding objectives should account for inputs (e.g., feed costs, husbandry costs, marketing costs) as well as for outputs such as income from weanling animals, surplus heifers and cull-for-age cows. The breeding objective is what we want to improve. Decisions about which traits should be included in the objective should be based purely on economic grounds, and not on whether they are difficult or easy to measure or change genetically. The traits in the breeding objective are the ends, whereas the characters used as selection criteria are the means used to achieve the ends. Selection criteria are utilized to make selection decisions, and these criteria are the characters we assess to estimate the breeding value of the animals.

Breeding objectives for beef cattle production are required to guide the primary tools of genetic improvement currently available to the breeder: (1) selection and (2) crossbreeding. Within-herd selection provides sustained, continuous improvement in breeding value (profitability?), and provides the basis for all breed genetic evaluation schemes. Alternatively, crossbreeding represents an opportunity to combine breeds to enhance productivity, and also provides an opportunity to make progress in one generation that would otherwise require generations of selection to obtain. Advances due to a well defined and executed selection program are cumulative. A structured crossbreeding program (e.g., rotational, or criss-cross) attempts to maximize productivity through combining of economically important characters of different breeds and exploiting heterosis. Maintenance of increasing productivity can only occur if the commercial producer is purchasing performance recorded cattle of superior genetic merit from seed-stock producers with well defined selection programs.

The present research is based upon raising beef cattle in Australia. While the production and marketing systems may be different to those of American beef cattle production, the example presented shows the potential importance of well defined breeding objectives in improving the efficiency of beef cattle production.

Development of the Breeding Objective

A hierarchical structure seemingly exists in the beef cattle industry. Bull breeding herds (which breed their own male and female replacements) and commercial herds (which purchase bulls from bull breeding herds) can be distinguished. Commercial herds produce virtually all the product (meat), but they are dependant on bull breeding herds for permanent genetic improvement. Thus, bull breeding herds should define their breeding objectives in accordance with the characteristics of commercial herds, and this was the approach taken in the present study.

The development of the breeding objective can be described in terms of the following four phases:

I. Specify breeding, production and marketing system.
II. Identify sources of income and expense in commercial herds.
III. Determine biological traits influencing income and expense.
IV. Derive an economic value of each trait.

Each of these phases is described in detail below using as an example Australian beef production.

I. Breeding, production and marketing system.

Breeding system. Specifying the breeding system involves defining the role of the breed (for which the breeding objective is being developed) in the production system. In broad terms, the roles could be general purpose, maternal line, or terminal sire line. The role of the breed influences the fraction of genes present in various segments of the production system. Pure breeding was assumed in the present context, the breed in question being used in a general purpose role. For example Hereford, Angus, Shorthorn and other British breeds are often used in such a role.

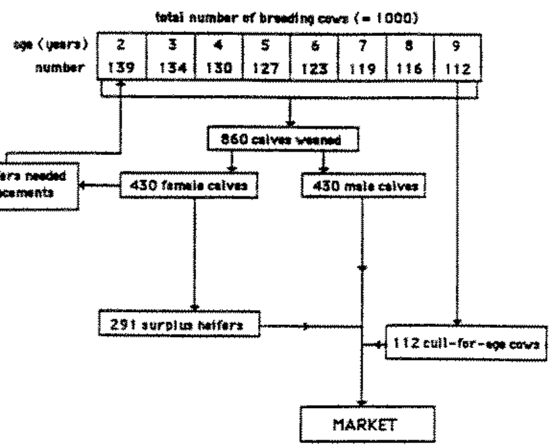
Production and marketing system. Specification of the production and marketing system involves the description of how animals are

[13] Authors are Research Geneticist, USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana, and Senior Livestock Geneticist, South Australian Dept. of Agriculture. Research described in this report was completed while the senior author was J.S. Davies Senior Research Fellow in Beef Cattle Breeding at the Waite Agricultural Research Institute of the University of Adelaide, South Australia.

fed and managed, the age composition of the herd, the replacement policy, and age(s) of the slaughter animals.

The feeding regime assumed was that of grazing animals, consistent with the fact that Australian beef is almost entirely derived from pastures. Standard management practices of drenching, lice treatment, vaccination, branding, tagging and some veterinary assistance were assumed. Figure 1 shows the herd composition. Defining herd composition aids in identifying age and numerical distribution of the herd, the number of replacements required each year, the number of animals of all classes available for market each year, and is required in the calculation of the economic values, as not all traits are expressed with the same frequency, or at the same time.

Figure 1. Herd composition.



Heifers were assumed to be mated at approximately 15 months of age to calve at two years. Calving takes place in late summer/early autumn (March through April). Rebreeding occurs at the beginning of June. Calves are weaned at 8 to 10 months of age. It was assumed that slaughter of male calves and of heifers was at a fixed age, rather than at a fixed weight.

II. Sources of income and expense in commercial herds.

The identification of sources of income and expense in commercial herds enables the development of a profit equation, where profit (P) is a function of income (I) and expense (E):

$$P = I - E.$$

Income is composed of the value of steers, surplus heifers and cull-for-age cows. Expenses identified includes feed intake, husbandry costs and marketing costs for the three classes of livestock. Fixed costs are also identified in the expense part of the equation, where fixed costs are those costs incurred by the producer (e.g., rates, interests, business costs) independent of the level of herd production. All other costs are known as variable costs and vary with the level of herd production.

Carcass values and husbandry and marketing costs are presented in Table 1. These values were extracted from information published weekly by The Stock Journal of South Australia, and from the publication "Farm Costs and Returns - a budget guide for 1987", prepared by the Economics Division of the South Australian Department of Agriculture. Feed costs were calculated based on agistment rates in the following manner. A cow's yearly feed intake was estimated to be 9,904 lb dry matter (DM). The agistment[14] rate over 12 months (52.14 weeks) at A$2.60 per week is A$135.60, which yields a cost per lb of DM of A$0.014. Feed costs per lb of DM for all classes of cattle were assumed to be the same.

III. Determination of biological traits influencing income and expense.

Here the profit equation is expressed as a function of biological traits that impact on income, expense, or both. The biological traits assumed to have an effect on income and expense derived from the herd are listed in Table 2. Details explaining the rationale behind the calculation of each economic value are given elsewhere (Ponzoni and Newman, 1989). In some instances the justification for inclusion of a trait in the breeding objective may be immediately obvious, but in others it may not. In the case of calving day (CD) it can be shown that with a restricted calving period a reduction of one day in the average CD will result in a one percent improvement in calving percentage.

The profit equation can be expressed in many different ways. For example, grouping terms by classes of cattle and calculating returns and expense in one year yields:

$$P = (P_{\text{male calves}} + P_{\text{heifers}} + P_{\text{cull cows}}) - \text{fixed costs}$$

where the right hand sides (P_) represent income minus expenses from the three sources of product. Each of these terms were then expressed as a function of traits in the breeding objective.

IV. Derivation of the economic value of each trait.

Not all traits in the breeding objective are expressed with the same frequency, or at the same point in time. To account for this we used the "discounted gene flow" method (McClintock and Cunningham 1974). A discount rate of 5 per cent was applied and a period of 20 years was considered. With the "discounted gene flow" method income and expense accrued early in the life cycle of the herd receive greater weight than income and expense accrued later.

[14] Agistment is a word used in the U.K., Australia and New Zealand to describe the feeding of livestock on leased pasture.

Table 1a. Description and value of products for production system.

Class	Live weight	Carcass weight	Fat depth (12/13 rib)	Price per kg[a]	Price per head
Male calves (9 mo old)	638 lb	352 lb	.3 in	$1.95	$312.00
Heifers (15 mo old)	770	440	.3	1.80	360.00
Cull cows	1,166	583	-	1.65	437.25

[a]All monetary values in Australian dollars; multiply by .75 to convert to U.S. dollars.

Table 1b. Value of expenses for production system.

Expense	Calves	Heifers	Cows
Feed	all classes: $0.014 per lb of dry matter in pasture		
Husbandry (per head)	$2.68[b]	$4.43[b]	$6.25[c]
Marketing (per head)	$21.62	$26.75	$30.61

[b]Includes drench, lice treatment, vaccine, brand, tag.

[c]Includes drench, lice treatment, veterinary.

Table 2. Biological traits included in the breeding objective because of their effect on income and expenses derived from the herd.

Effect on profit	Product or activity	Class of cattle	Traits
Income	Surplus offspring	Calves	Calving day (CD) Carcass weight - direct (9CWd) Carcass weight - maternal (9CWm) Fat depth (9FD)
		Heifers	CD, carcass weight (hCW) fat depth (hFD)
	Cull-for-age animals	Cows	Carcass weight (cCW)
Expense	Feeding	Calves	Feed intake (9FI) CD
		Heifers	Feed intake (hFI) CD
		Cows	Feed intake (cFI)
	Husbandry	Calves	CD
		Heifers	CD
	Marketing of surplus cattle	Calves	CD, 9CWd, 9CWm, 9FD
		Heifers	CD, hCW, hFD
		Cows	cCW

Choice of Selection Criteria

The development of the breeding objective involves making decisions of an economic nature. It is not until we begin making considerations about the evaluation of animals that genetic considerations are strictly relevant. Some traits in the breeding objective may be difficult or expensive to measure, while theremay be characters highly correlated with traits in the objective, but that are not themselves included in it. This is the reason why only very rarely there will be an exact correspondence between the set of traits in the breeding objective and the set of characters used as selection criteria.

Table 3 shows the characters chosen as selection criteria and the information from relatives assumed available for the examination of the consequences of selection. The characters were, of course, chosen because their recording is feasible on-farm and because of their genetic correlations with the traits in the breeding objective. The heritabilities, genetic and phenotypic correlations among all traits (breeding objective) and characters (criteria) assumed in our calculations were chosen after a search of the literature. All of this information is combined into a selection index (which is signified by I_5, the 5 corresponding to 5% discounting), and selection of animals is based upon the value of their index.

Table 3. Characters chosen as selection criteria and information assumed available from relatives.

Characters	Relatives
Nine month live weight (9LW) Ultrasound and fat record (US)	Individual Sire Dam 30 paternal half sibs 2 maternal half sibs
Calving Day (CD)	Dam (3 records) 15 paternal half sisters (one record)

Results and Discussion

One of the merits of the approach presented in this paper is that it enables the investigation of a broad range of situations, which may be of specific interest to individual breeders. Here we present some numerical results illustrating this point.

The contribution of each trait to overall gain in economic units.

One method of measuring how useful selection (based upon the index composed of the characters from Table 3) has been is to look at the percentage gain in economic units accounted for by each trait following index selection. The following points emerge: (1) calving day (CD) was the trait making the greatest contribution; (2) the contribution of the maternal component of carcass weight (9CWm) was negligible when compared to that of other traits, contrary to current thinking given the breeding, production and marketing system assumed, and (3) several traits changed in the 'wrong' direction (notably cow feed intake). When dealing with multi-trait objectives it does not necessarily follow that because a trait has economic value it has to be 'improved'. Rather, the selection pressure placed upon it will depend on which other traits are in the breeding objective, and on the information available for the estimation of breeding values.

Effect of ignoring the economic value of feed intake in the breeding objective.

Setting the value of feed costs at zero, in broad terms, had the effect of approximately halving the gain in CD, while doubling the magnitude of the change in all other traits except 9CWm, in which case the sign of the change was reversed.

Assuming feed costs are equal to zero is the same as ignoring the need to account for such costs in the definition of the breeding objective. Emphasis was shifted from reproduction (CD) to growth traits (CW and FD), with a consequent increase in feed intake. The 17% loss of efficiency resulting from ignoring feed intake in the breeding objective is large enough to justify careful consideration of feed costs in future development of breeding objectives for beef cattle.

It is thus suggested that any examination of economic benefits of genetic gains which ignores correlated responses in feed intake can seriously overestimate those benefits.

Effect of the inclusion of yearling weight or deletion of calving day from the index.

The consequences of selection can change depending on the information (selection criteria) available for the estimation of breeding values. The addition of yearling weight to the index changed the magnitude of the genetic gain in some traits. Favorable changes in carcass weights were accompanied by unfavorable changes in feed intake. The accuracy of the index changed very little with respect to that of I_5. In practice, this means that in the context of the breeding objective being examined, if live weight at nine months of age has been recorded, the small gain from recording another live weight at approximately 15 months of age may not compensate for the extra cost. The deletion of calving day from the index had a spectacular effect, reversing the sign of the gain of two traits (CD and 9CWm), and most importantly, halving the accuracy of the index with respect to that of I_5. CD is usually recorded in bull breeding herds so that calf live weights can be adjusted for age. These results indicate that if CD is a trait in the breeding objective, it is highly desirable that the system of genetic evaluation utilize the CD records in the overall index of economic merit. The accuracy of the estimated breeding value of CD using I_5 was 0.33, but decreased to 0.09 when CD was removed from the index.

Final Remarks

In this paper we presented a description and illustration of the development of breeding objectives for beef cattle. Only a few alternatives were investigated, but the model enables the examination of the effect of variations in herd composition, product values and costs, phenotypic and genetic parameters, breeding system, etc. The objectives developed under different assumptjons can be compared, and the effects of refinements in the procedures used can be precisely assessed. The adoption of an approach such as that outlined here in the design of a beef cattle breeding program could further enhance the benefits derived from performance recording and the profitability of beef production. Similar projects are planned for the development of breeding objectives for the Northern Great Plains.

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PERFORMANCE OF BEEF CATTLE OF DIFFERENT BIOLOGICAL TYPES UNDER RANGE ENVIRONMENTS. I. REPRODUCTION AND CALF GROWTH RATE

W.L. Reynolds, J.J. Urick and B.W. Knapp[15]

Introduction

Beef cattle production is one of the major industries in the western range area of the United States. Most of the beef cattle in these states obtain their nutrients from grazing grasses or forbs on the range. Supplemental forages and sources of energy may be fed if necessary, particularly during the winter months. Production of forage and forage quality is highly variable from year to year depending upon amount and distribution of rainfall. Temperatures in winter and also in summer can be extreme resulting at times in a harsh environment.

Beef cattle differing in size and milk production needed to be evaluated under western range conditions to provide guidelines to selection and management practices for optimum beef production. An objective was to evaluate these biological types as cows and the performance of their progeny from birth to market.

This paper reports some of the factors affecting reproduction and calf growth rate of mating sires of different breeds to Hereford dams to produce first-cross calves. This paper also provides results of postweaning growth rate and pregnancy rate of first-cross heifers and factors affecting calving of 2-year-old heifers, calf survival and performance of calves from 2-year-old heifers. Preliminary data of this study were reported in the 1981 and 1984 Field Day Reports. Results reported here were analyzed statistically and the means differ only slightly from previous reports.

Methods

This study involves the cooperation of the Fort Keogh Livestock and Range Research Laboratory (LARRL), Miles City, Montana, the Meat and Animal Research Center (MARC), Clay Center, Nebraska and the State Experiment Stations of Montana and Nebraska. The report contains results from studies conducted at LARRL.

Initially for this study, four types of F_1 crossbred females representing different biological types of cattle were produced. These were the Angus X Hereford, Red poll X Hereford, Pinzgauer X Hereford and Simmental X Hereford. These animals were produced in years 1975 through 1978. A herd of approximately 280 Hereford females were bred by artificial insemination to Angus, Pinzgauer, Red Poll and Simmental bulls to produce the F_1 crossbreds. This program was repeated yearly until over 60 F_1 females of each sire breed were obtained. In 1976, a group of Tarentaise X Hereford F_1 females were donated by breeders throughout Montana, and in 1977, Tarentaise bulls were included as a sire breed. Many of the same sires used at MARC were used in this study.

Existing information suggest that the Simmental and Pinzgauer should be among the larger sire breeds in mature size and the Angus, Red Poll and Tarentaise among the smaller breeds. The Simmental were expected to have higher milk production than the Pinzgauer, and the Red Poll and Tarentaise to have higher milk production than the Angus.

The first-cross heifers were kept to form a herd of breeding females and were fed to gain about 1.3 pounds daily during the winter after weaning. Heifers were placed on native grass pasture about April 20 each year. Yearling crossbred heifers were exposed to Shorthorn bulls in multiple sire herds for 45 days. All of the offspring, both male and female, from the first-cross dams were placed on feed after weaning in the fall.

Results

Table 1 shows the results of mating sires of different breeds to Hereford dams to produce first-cross offspring. Statistical differences were found in gestation length and percent calving difficulty with the dams mated to Angus sires having the shortest gestation length and dams mated to medium-size sires having the lowest amount of calving difficulty. This was caused by the lighter birth weight of Angus- and Red-Poll-sired calves. No difference was found in the average daily gain of calves from the four sire breeds, but Simmental X Hereford calves were heavier than others at weaning and in 200-day weight.

[15] Authors are: W.L. Reynolds, Retired Geneticist, J.J. Urick, Retired Geneticist, B.W. Knapp, Statistician, all from USDA-ARS, Ft. Keogh Livestock and Range Research Laboratory.

Table 1. Means for Hereford dams mated to sires of different breeds to produce first-cross calves.

Item	Breed of Sire			
	Angus	Red Poll	Pinzgauer	Simmental
Number of calves	165	152	152	161
Gestation length, days	284.8	289.0	287.2	288.5
Calving difficulty score[a]	1.4	1.3	1.6	1.7
Calving difficulty, %	12	12	20	26
Calf death loss, %				
Birth	4.1	.2	3.0	2.9
Preweaning	8.1	7.3	11.7	7.2
Birth weight, pounds	76.6	82.2	88.9	88.9
Average daily gain -				
birth to wean, pounds per day	1.67	1.57	1.60	1.69
200-day weight, pounds	412	398	410	427

[a] 1 = no assistance, 2 = easy pull, 3 = hard pull.

Table 2. Postweaning growth traits (pounds), pregnancy rate (%) and fall condition score of first-cross heifers from Hereford dams.

Item	Breed of sire of 2-yr-old heifers				
	Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Number	65	71	66	73	31
Initial weight, lb.	430	406	438	432	436
140-day test weight, lb.	631	598	642	649	643
Gain, init. to 140 days, lb.	201	192	204	217	207
Prebreeding weight, lb.	700	671	710	726	711
Fall weight, lb.	831	805	849	869	845
Gain, 140 days to fall, lb.	200	207	207	220	202
18-month weight, lb.	861	846	882	916	886
Fall condition score[a]	7.2	6.2	6.1	6.6	6.3
Pregnancy rate, %	90.0	83.3	91.3	73.8	94.2

[a] Condition score: 1 = extremely thin, to 10 = very fat.

The results of postweaning growth are shown in Table 2. The Red Poll X Hereford heifers gained at the lowest rate for the first 140 days while the Simmental X Hereford heifers gained the most rapidly during this period and from 140 days to fall. Pregnancy rates of the medium size heifers (Angus-, Pinzgauer- and Tarentaise-sired) had the highest overall pregnancy rate while the Simmental-sired heifers had the lowest pregnancy rate. In years when growth rate was highest, all breed groups had over 90% pregnancy rate in a 45-day breeding season. Therefore, all groups have a potential for high pregnancy rates if nutritional levels are adequate.

The results of percent calving difficulty of the first-cross 2-year-old heifers mated to Shorthorn sires to produce 3-breed cross calves are shown in Table 3. First-cross heifers from Angus and Tarentaise sires had the least amount of calving difficulty and first-cross heifers from the Pinzgauer and Simmental sires the most. Most Angus-sired heifers that required assistance required mechanical help. However, a number of Red Poll- and Simmental-sired heifers required only hand assistance in order to calve.

Death loss of calves in the first 72 hours was greater for the calves from the first-cross Angus X Hereford dams. Calves from first-cross 2-year-old heifers differed as might be expected in birth weight with calves from Pinzgauer X Hereford and Simmental X Hereford heifers having heavier calf birth weights than the other breed groups. Calves from 2-year-old heifers did not differ statistically in growth rate from birth to weaning or in weaning condition score.

Table 3. Dystocia, calf death loss and production to weaning of progeny from 2-yr-old crossbred heifers mated to Shorthorn bulls.

Item	Breed of sire of first-cross 2-yr-old heifers				
	Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Calving difficulty %, none vs assisted	28.6	40.8	53.3	60.4	28.6
Mechanical assistance, %	27.0	28.1	45.1	39.4	--
Calf death loss 1st 72 hours, %	15.5	3.1	8.6	3.4	5.4
Calf survival rate Birth to weaning, %	83.1	94.4	87.3	93.2	86.5
Birth weight, lb.	69.1	72.9	78.9	76.0	73.7
ADG birth to weaning, lb.	1.71	1.71	1.76	1.80	1.85
Weaning age, days	197	195	197	195	195
Weaning weight, lb.	408	406	428	427	436
200-d weight, lb.	413	414	432	436	445
Weaning condition score[a]	6.6	6.3	6.3	6.5	-6.7

[a] 1 = extremely thin, 10 = very fat.

Calves from first-cross 2-year-old Pinzgauer-, Simmental- and Tarentaise-sired females were heavier in 200-day weight than calves from first-cross 2-year-old Angus- and Red Poll-sired heifers; however, this was primarily due to differences in birth weight.

Conclusions

These studies show that no one breed or breed cross exceeds in all calving and weaning traits. The results also indicate the initial matings or first-cross mating of breeds is a good indicator of the production or rank of the first-cross 2-year-old females as dams. As an example, breeds mated to Hereford dams which resulted in higher levels of calving difficulty, their first-cross heifers also had higher levels of calving difficulty. Large breed differences were found in calf birth weight but no statistical breed differences were found in calf growth rate. These results show selection of a breed should be carefully considered based upon the level of nutrition that can be provided to yearling heifers, level of management that can be imposed at calving and also nutrition level of lactating heifers.

PERFORMANCE OF BEEF CATTLE OF DIFFERENT BIOLOGICAL TYPES UNDER RANGE ENVIRONMENTS. II. POSTWEANING GROWTH AND CARCASS CHARACTERISTICS OF FIRST-CROSS STEERS AND THREE-BREED CROSS HEIFERS AND STEERS

J.J. Urick, W.L. Reynolds, M.D. MacNeil and B.W. Knapp[16]

Introduction

This paper reports the postweaning growth and carcass data of the first-cross steers of different biological types produced in the experiment described by Reynolds in this Field Day Report (1990). The paper also reports on the postweaning growth and carcass traits of the offspring of the first-cross heifers and cows of different biological types. By design, all first-cross heifers were mated to Shorthorn bulls to reduce calving difficulty of 2-year-old heifers. The 2- to 5-yr-old first-cross cows were mated to Charolais bulls as a terminal sire breed to obtain maximum growth of the steers and heifers produced. Preliminary data of the growth and carcass traits of the offspring of the first-cross heifers were previously published in the 1981 and 1984 Field Day Reports.

Methods

First-cross steers from Hereford dams: The original experiment included Angus X Hereford, Red Poll X Hereford, Pinzgauer X Hereford and Simmental X Hereford groups, which were produced in years 1975 to 1978. In the final year, a group of Tarentaise X Hereford were produced for evaluation. After weaning in mid-October each year, the steer calves were assigned to individual pens (7 X 45 feet) with access to individual waterers. They were given a 2-week adjustment period to allow the steers to adapt to the facilities and rations. The ration fed ad libitum, consisted of 57.1% corn silage, 33.5% cracked barley and 9.4% protein-mineral

[15] Authors are: Urick and Reynolds are Retired Geneticists, MacNeil a Quantitative Geneticist and Knapp a Statistician with the USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana.

supplement on a dry matter basis and provided approximately 2.62 Mcal energy/kg dry matter. The steers were weighed at 28-day intervals and feed consumed totaled for each period throughout the feed test. A sequential slaughter was used to permit adjustment to weight, age and fat depth constant endpoints. The initial slaughter group coincided with the time when 60% of the Angus X Hereford steers were estimated by visual appraisal to grade choice (small amount of marbling). At that point, a random one-third of the steers of each sire breed was slaughtered at a local packing plant. A second random one-third were slaughtered 28 days later and the final one-third, 28 days thereafter. The final weight was the unshrunk weight off feed before slaughter. Estimates of marbling score, kidney, pelvic and heart fat were obtained by USDA graders following a 36-hour chill. Area of rib eye and fat thickness at the 12th rib were obtained from tracings taken on acetate paper. Marbling scores were coded as follows: slight (sl), sl- = 8, sl = 9, sl+ = 10, small (sm), sm- = 11, sm = 12 and sm+ = 13. Percent cutability was calculated using the Beef Cattle Improvement Federation (BIF) standards, which express the percentage of trimmed (to 1/2-inch of surface fat), boneless retail cuts from the round, loin, rib and chuck.

Since steers of this experiment were slaughtered at three different time periods, the breed group growth and carcass comparisons were made at adjusted age and time endpoints. Average daily gain on test was calculated from initial weight to 382 days of age, and carcass evaluations were made from steers slaughtered at the adjusted age of 242 days.

Results

First-cross steers from Hereford dams. The ranking of breed of sire groups for initial weight (Table 1) closely follows their ranking for weaning weight as shown in the report by Reynolds et al. (Field Day, 1990). Angus-, Red Poll- and Pinzgauer-sired calves had similar initial weights. Simmental-sired calves were the heaviest and were significantly heavier than Red Poll and Pinzgauer. Tarentaise-sired calves were intermediate for initial weight. Postweaning average daily gain of the Simmental-sired steers to 382 days of age exceeded the ADG of the Angus, Red Poll and Pinzgauer steers. The Tarentaise steers were intermediate for ADG. Simmental-sired steers were heavier at 382 days and exceeded by 78 pounds the average weight of the Angus-, Red Poll- and Pinzgauer-sired steers, which were similar to each others. Tarentaise-sired steers were not significantly different than the other groups.

Feed efficiency: In this set of data, feed efficiency was calculated as Mcal of feed intake for each unit of body weight gain. When the sire breed groups were compared at age and weight constant endpoints, breed rankings for feed efficiency were mostly in the same order as they were for average daily gain. Simmental-sired steers required less feed per unit of gain than Angus- and Red Poll-sired steers to reach 382 days of age and 882-pound weight. Feed conversion ratios of Simmental, Pinzgauer and Tarentaise were not significantly different, and the Angus- and Red Poll-sired steers were similar at age and weight endpoints.

When feed efficiency of the five breed groups was adjusted to a constant backfat thickness (.5 inch), the breed rankings differed from the results for age and weight endpoints. Simmental-sired steers were intermediate for feed conversion and did not differ from any of the other breed groups. Angus-sired steers used less energy per unit of gain to reach .5 inch of backfat than the Red Poll-, Pinzgauer- or Tarentaise-sired steers, which were similar. The favorable results of the Angus-sired steers at the fat constant endpoint may be partially explained by the fact that the Angus-sired steers were lighter and younger than the other breed groups when reaching .5-inch backfat. These factors favor lower feed requirement for maintenance and growth. The results of this study verify other studies, which have found that cattle of different biological types may vary in their utilization of feed in different feeding management schemes.

Carcass traits: Carcass data as shown in Table 1 are comparisons of the breed groups when adjusted to constant time on feed (242 days). The Simmental-sired steers ranked highest for carcass weight, area of rib eye and cutability percent. For the same traits, the Pinzgauer- and Tarentaise-sired steers were similar and ranked higher than the Angus- and Red Poll-sired steers. At this endpoint, the rankings of breed groups for marbling score were from high to low, Angus, Tarentaise, Red Poll, Pinzgauer and Simmental. Beef from all breed groups were considered acceptable for consumer demand even though there were some differences in marbling score.

At an adjusted weight endpoint of 882 pounds breed differences were relatively small with the exception that Angus-sired steers were predicted to have an increased amount of fat over the rib, in the body cavity and intramuscular, all of which contribute to lower cutability. At an adjusted backfat endpoint (.5 inch), the Angus and Red Poll were predicted to have lower final weight and carcass weight, smaller rib eye area and retail weight than the other breed-sired steers.

Three-breed cross heifer and steer calves from first-cross 2-year-old dams and Shorthorn sires. The first-cross yearling heifers produced in Phase 1 were bred to Shorthorn sires to produce three-breed cross progeny. At 2 years of age, these heifers calved in April and May and their calves were weaned around October 15 each year. Calves were not creep fed on pasture. After weaning, the heifer and steer calves were given a 14-day adjustment period to become accustomed to the facilities and diets. The calves were initially fed for 140 days on a high roughage ration (corn silage and protein supplement - 2.52 Mcal/kg feed). The finishing period for steers was 118 days and 112 days for heifers and the diet for both sexes consisted of corn silage and protein supplement and four pounds of cracked barley (2.62 Mcal/kg feed). The final weight was taken at the end of test with no shrink. Carcass data were taken at the local packing plant. Procedures used for collecting carcass data from the three-breed cross steers and heifers were the same as for first-cross steers.

Steer and heifer progeny data from the first-cross 2-year-old heifers and Shorthorn sires are shown in Tables 2 and 3. The calves of this data set contained only one-fourth the inheritance of each maternal grandsire breed in comparison to the first-cross steers of phase 1 that had one-half the inheritance of a sire breed.

Table 1. Postweaning growth and carcass traits of first-cross steer calves from Hereford dams.

Item	Breed of sire: Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Number of calves	63	56	56	58	26
Initial weight, lb.	390	368	384	415	410
ADG initial to final wt., lb. (196 days)	2.23	2.22	2.30	2.48	2.29
Weight of steers at 382 days of age (lb.)	827	805	833	900	860
Carcass traits adjusted to 242 days on feed:					
Slaughter weight., lb.	944	924	957	1,014	968
Hot carcass weight, lb.	564	557	558	604	575
Dressing, %	59.7	60.3	58.3	59.6	59.4
Rib eye area, sq. in.	11.3	11.3	11.7	12.5	11.9
Fat thickness, in.	.68	.56	.45	.45	.43
KHP fat, %,	2.8	3.0	2.5	2.5	3.0
Cutability	49.1	49.7	51.3	51.5	51.1
Marbling score	12.7	10.8	10.4	10.2	11.3

Table 2. Postweaning growth and carcass traits of heifers from Shorthorn-sires and first-cross heifers from Hereford dams.

Item	Breed of sire of first-cross 2-year-old heifers: Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Postweaning growth					
Number of calves	19	24	20	30	18
Initial weight, lb.	404	400	431	432	452
140-day test weight, lb.	675	656	689	704	758
Gain/day, initial to 140 days, lb.	1.92	1.83	1.85	1.95	2.19
Final test weight., lb.	917	880	959	950	984
Gain, 140 days to final weight, lb.	2.15	1.98	2.37	2.15	2.00
Gain, initial to final weight, lb.	2.03	1.90	2.09	2.04	2.10
Carcass traits					
Hot carcass weight, lb.	517	504	538	538	573
Dressing %	56.3	57.3	56.1	56.6	58.3
Rib eye area, sq. in.	10.4	10.3	11.3	11.3	11.5
Fat thickness, in.	.54	.51	.49	.46	.49
KHP fat, %	3.1	3.5	3.2	2.9	3.0
Cutability, %	49.7	49.7	50.4	50.6	50.2
Marbling score	14.6	13.8	14.1	13.8	13.9
Percent choice	100	96	81	83	83.

Breed differences in the heifer calves (Table 2) from the first-cross cows were greater for all growth traits than in the steers (Table 3). In the heifers, the initial calf weights from first-cross cows of different breeds ranged from 400 to 452 pounds and for final weight from 880 to 984 pounds. In the steer calves, the range in initial weights were from 428 to 454 pounds and for final weight 994 to 1,038 pounds. In the heifers, there was a tendency for breed group rankings for the 140-day initial feeding period to change for some groups during the final 112-day period. The heifer calves from Tarentaise maternal sire breed ranked highest for ADG during the 140 days but ranked lowest in the final period. In the steer groups, differences for growth in both growing periods were small.

The carcass data comparisons are shown in Tables 2 and 3. As observed for feedlot growth traits, heifer carcass traits related to

Table 3. Postweaning growth and carcass traits of steers from Shorthorn sires and first-cross heifers from Hereford dams.

Item	Breed of sire of first-cross 2-yr-old heifers				
	Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Postweaning growth					
Number of calves	25	29	26	18	23
Initial weight, lb.	440	428	454	433	448
140-day test weight, lb.	719	710	753	712	744
Gain/day, initial to 140 days	2.00	2.02	2.14	2.00	2.12
Final test weight, lb.	998	994	1,038	1,014	1,016
Gain/day, 140 days to final weight, lb.	2.35	2.40	2.41	2.56	2.30
Gain/day, initial to final weight, lb.	2.16	2.20	2.26	2.36	2.20
Carcass traits					
Hot carcass weight, lb.	570	564	595	578	579
Dressing %	57.2	56.7	57.4	57.1	57.0
Rib eye area, sq. in.	10.7	11.0	11.3	11.5	11.5
Fat thickness, in.	.51	.45	.44	.43	.41
KHP fat, %	3.13	2.95	3.09	2.93	2.92
Cutability %	49.5	50.2	50.1	50.6	50.8
Marbling score	14.3	11.9	12.9	11.4	13.2
Percent Choice	92	84	73	67	96.

growth were more different than steer traits among dam breed groups. In the heifers, the maternal grandsire breed groups of Pinzgauer, Simmental and Tarentaise ranked higher than the Angus and Red Poll groups for carcass weight, area of rib eye area and percent cutability. The Angus and Red Poll heifer groups had higher percentages of Choice carcasses.

Differences among steer breed groups for feedlot test performance and for carcass growth traits were small. Differences among steer breed groups for marbling score were greater than for growth. Carcasses from the Angus-sired first-cross females ranked the highest for marbling and were followed by Tarentaise, Pinzgauer, Red Poll and Simmental in that order.

Three-breed cross calves from 3- to 6-year-old dams and Charolais sires. Calves for this data set were produced by mating Charolais sires via multiple sire matings to the five types of the first-cross dams on the range. The dams were 3 to 6 years of age, which produced calves as 2-year-old dams from Shorthorn sires.

Offspring of Shorthorn and Charolais breeds cannot be compared in this experiment because they are from cows of different ages. Calves in this data set were born mostly in April and May and weaned around October 15. Calves were not creep fed on the dams. After an adjustment period of 14 days, the calves were separated into heifer and steer groups and assigned at random to outside pens. Both heifers and steers were fed a diet consisting of corn silage, cracked barley and protein supplement but with a slightly lower energy for heifers (2.77 Mcal/kg) compared to 2.82 Mcal/kg for steers. Steers were fed for an average of 258 days and heifers 230 days.

Results of feedlot growth of Charolais-sired calves are shown in Table 4 for heifers and Table 5 for steers. The heifer calves from the five different breeds of first-cross dams showed larger differences for all growth traits than the steer calves. The breed group means in heifers for ADG on test was from 2.27 to 2.44 pounds and the range in final weight was from 1,014 to 1,082 pounds. In the steers, the range for ADG was 2.58 to 2.64 and for final weight 1,179 to 1,209 pounds. The heifer vs steer results from this set of calves from Charolais sires compared closely to that from the first set where the calves were from 2-year-old heifers and Shorthorn sires. It is, therefore, postulated that the conditions under which these calves were fed at this location were less favorable than needed for the steer calves to express their full potential for growth inherited through the maternal grandsire. The heifers grew slightly faster if their dams were produced from the larger European breeds of sires in comparison with dams from Angus and Red Poll breeds.

Carcass traits of Charolais-sired calves are presented in Tables 4 and 5. Among the heifer groups, those from the Simmental-sired first-cross dams had the heaviest carcasses and ranked high along with Pinzgauer heifers for area of rib eye and percent cutability. The heifer carcasses from all five first-cross dam breeds were not different for marbling score. In the steer calves, the carcass weights of the five breed groups were similar. The Pinzgauer and Simmental steers had a higher percent cutability due to the advantage of larger rib eye area and lower backfat thickness. The steers with 25% Angus inheritance had the highest marbling scores.

The steer carcasses from Red Poll-, Pinzgauer-, Simmental- and Tarentaise-sired first-cross dams were similar for marbling. Even though the marbling scores among the five steer breed groups were small, the overall summary of carcass grades (Table 5) reflected some differences in the percentage of Choice-grading steer carcasses among the groups. Percentage of carcasses grading Choice in the

Table 4. Postweaning growth and carcass traits of heifers from Charolais sires and first-cross cows from Hereford dams.

Item	Breed of sire of first-cross cow				
	Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Postweaning growth					
Number of calves	97	81	66	73	46
Initial test wt., lb.	481	491	495	517	507
140-day test wt., lb.	799	821	827	853	824
Gain initial to 140 days, lb.	2.28	2.36	2.31	2.40	2.27
Final test wt., lb.	1,014	1,032	1,043	1,082	1,031
Gain/day 140 days to final wt. lb.	2.35	2.30	2.37	2.50	2.27
Gain/day initial to final wt., lb.	2.31	2.34	2.37	2.44	2.27
Carcass traits					
Hot carcass wt., lb.	603	614	618	642	616
Dressing %	59.5	59.5	59.2	59.3	59.8
Rib rye area, sq. in.	12.3	12.4	13.0	13.0	12.5
Fat thickness, 12th rib, in.	.42	.38	.34	.37	.34
KHP fat, %	2.5	2.6	2.4	2.5	2.8
Cutability, %	51.2	51.4	52.1	51.7	51.6
Marbling score	12.2	12.4	11.8	11.1	11.2
Percent Choice	64	72	56	63	65.

Table 5. Postweaning growth and carcass traits of steers from Charolais sires and first-cross cows from Hereford dams.

Item	Breed of sire of first-cross cows				
	Angus	Red Poll	Pinzgauer	Simmental	Tarentaise
Postweaning growth					
Number of calves	81	85	67	65	43
Initial test wt., lb.	518	521	546	536	526
140-day test wt., lb.	890	899	914	901	894
Gain/day, initial to 140 days, lb.	2.66	2.70	2.64	2.61	2.63
Final test wt., lb.	1,179	1,189	1,209	1,195	1,180
Gain 140 days to final wt., lb.	2.57	2.56	2.61	2.58	2.52
Gain initial to final wt., lb.	2.61	2.64	2.63	2.60	2.58
Carcass traits					
Hot carcass wt., lb.	708	714	719	716	709
Dressing %	60.1	60.1	59.5	60.0	60.1
Rib rye area, sq. in.	12.7	12.7	13.3	13.5	12.9
Fat thickness, 12th rib, in.	.48	.48	.40	.40	.42
KHP fat, %	2.5	2.7	2.5	2.5	2.6
Cutability, %	50.2	50.1	51.0	51.2	50.7
Marbling score	12.4	11.8	11.7	11.8	11.3
Percent Choice	81	71	61	64	65.

three-breed cross steers from the Angus group was 81%, in comparison to 71% for Red Poll, 61% for Pinzgauer, 64% for Simmental and 65% for Tarentaise.

Conclusions

Angus, Red Poll, Pinzgauer, Simmental and Tarentaise breeds were compared as sire breeds for postweaning performance of first-cross steer progeny and as sire breeds of first-cross cows bred to produce three-breed heifer and steer progeny. Breed representation of each of the five breeds was 50% in the first-cross calves and 25% in the three-breed cross calves. In the evaluation of the first-cross calves, those from Simmental sires had heavier weights, gained slightly faster postweaning and had higher feed efficiency at age and weight endpoints. Calves by Pinzgauer and Tarentaise were intermediate and those by Angus and Red Poll the lowest. In the three-breed cross calves from first-cross dams, the ranking of the same breeds was similar as in the first-cross calves, but the breed differences in the three-breed calves was about one-half that of the differences in the first-cross calves. The maternal grandsire breed group differences for growth among heifer progeny were larger than among the steer progeny group.

For carcass traits related to growth, the rankings of the five breeds was similar to live animal weights and gains in the feedlot. There was a tendency for the faster gaining breed groups to have higher cutability but lower marbling scores and carcass grades. In the overall carcass grade evaluations, the Angus and Red Poll progeny groups had a higher percentage of carcasses in the Choice grade than did the other three breed groups.

HERITABILITY AND GENETIC CORRELATIONS OF GROWTH AND CARCASS TRAITS OF HEREFORD BULLS IN A RANDOMLY SELECTED HERD

W.L. Reynolds, J.J. Urick, D.A. Veseth, D.D. Kress, M.D. MacNeil and R.E. Short[17]

Introduction

Birth weight, weaning weight, yearling weight and pre- and postweaning growth rate, along with carcass traits are important economic characteristics. Many studies have been published on the heritabilities and genetic correlations of birth weight, growth rate and carcass traits of beef cattle. Most of these studies have used data from herds where sires were selected for a measure of increased growth. As a result, estimates of heritability and genetic correlation may be biased upward. The purpose of this study was to estimate heritabilities and genetic correlations for growth and carcass traits of bulls in a population where no selection was practiced for any trait. Comparing estimates of heritability and genetic correlation obtained in this study with the literature estimates from selected populations leads to a conclusion of bias due to selection if the literature estimates exceed those from the present study.

Methods

In 1975, 114 pregnant Hereford cows and yearling Hereford heifers from a completed linecross study were assigned at random to 10 breeding herds. The linecross Herefords were various combinations of Miles City Lines 1, 4, 6 and 10. The 10 herds were divided into two replications of five single-sire breeding herds. Since 1980, two replications of four single-sire breeding herds were maintained with a total of approximately 240 females exposed per year. One bull and an alternate were selected each year at random within a sire group, and cows were reassigned at random to breeding herds within replication. All heifers were exposed to bulls as yearlings, and random culling was practiced within older age groups to maintain herd size. No other culling was practiced except as a result of disease, injury or diagnosed reproductive abnormalities. All cows over 5 yr of age at the end of the breeding season were removed from the project after 1980. All bulls used in the project were 2 yr of age at the beginning of the breeding season.

A 60-d breeding season (June 15 to August 15) was used, and all calves were weaned at approximately 185 d of age in mid-October. Cows were managed under range conditions with winter supplement supplied as needed. Bull calves were moved to drylots after weaning and fed a growing diet consisting of 48% corn silage, 48.7% barley grain, 1.8% soybean meal, .5% urea on a dry matter basis, plus salt, minerals and vitamins. This diet was fed throughout the 168-d feed test.

After the 168-d test, bulls were fed the same diet but at a level for a growth rate of approximately 2 lb./d for most of the years. Length of time from end of 168-d feed test to slaughter and the concentrate level of feed fed varied in some years. Yearling bulls averaged 16.3 mo of age when sent to slaughter. Carcasses were graded and measured the day after slaughter. One side of each carcass was separated between rib 11 and 12, and marbling (small = 12, slight = 9, and traces = 6) and percent kidney, heart and pelvic fat (KPH), rib eye area and fat depth of the 12th rib were determined.

The 2-yr-old bulls went directly from grass pasture to slaughter, were in medium condition, and averaged 30 months of age. Carcasses had very little fat covering over the ribs and were practically devoid of marbling and KPH. There was a 5-yr lapse between the time a herd sire was born and when his offspring were slaughtered.

[17] Authors are: Reynolds and Urick are Retired Geneticists, MacNeil Quantitative Geneticist and Short, Research Physiologist with USDA-ARS, Fort Keogh Livestock and Range Research Laboratory. Veseth and Kress are with Dept. Anim. and Range Sci., Montana State University, Bozeman, Montana.

The regression of son's growth and carcass characteristics on those of their sires and the correlations among paternal half-sibs were used to estimate heritabilities and growth correlations. The son-sire regression procedure measures the degree of similarity between a sire and his offspring. The paternal half-sib procedure measures the extra degree of similarity among progeny of the same sire over and above the similarity of unrelated individuals in the same contemporary group. All analyses were conducted in cooperation with Montana State University, and Veseth et al. (1989) reported results of paternal half-sib analyses.

Results

The population represents a moderate growth rate group of Herefords. The adjusted means for birth weights, growth and carcass data for the bull calves are shown in Table 1. Comparison of the slaughter data for the 2-yr-old bulls with that of yearling bulls would indicate bulls increased in weight and rib eye area from 1 to 2 yr of age, but the rib eye area per unit of carcass weight was slightly less. Bulls also decreased in all measures of fat as they increased in age, i.e., fat covering over the 12th rib, marbling score and percent KPH fat. Dressing percent of 2-yr-old bulls were lower than that of yearling bulls, probably due to differences in carcass fat content.

Table 1. Least-squares means of traits of bulls slaughtered at two ages.

Trait	16-mo-old bulls No.	16-mo-old bulls Mean	2-yr-old bulls No.	2-yr-old bulls Mean
Birth wt., lb.	736	75.7	101	77.7
Preweaning daily gain, lb.	616	1.65	101	1.67
Weaning wt, lb.	616	380.8	101	383.0
Daily gain on test, lb.	616	2.55	101	2.53
Final test wt., lb.	616	809.8	101	816.2
Slaughter wt., lb.	401	1,035.1	101	1,282.6
Carcass wt., lb.	401	610.0	101	693.9
Dressing percent	401	58.8	101	54.1
Rib eye area, sq. in.	401	12.8	101	14.2
Rib eye/cwt. of carcass wt., sq. in.	401	2.10	101	2.05
Marbling score[a]	401	7.6	101	
Kidney, pelvic and heart fat, %	401	1.0	101	

[a] Small = 12, Slight minus = 8, Trace + = 7.

Heritabilities. The estimated heritability of birth weight in this unselected population of Hereford cattle averaged .20. This estimate appears lower than the average for birth weight of .45 reported in the literature but does fall within the range of estimates typically reported. We conclude there is no need to change selection procedures that are presently being recommended to the industry based on these results.

The heritabilities in this study (Table 2) of an unselected population of bulls for growth traits were similar to those reported in much of the literature. Heritability estimates of .19 and .22 were found for preweaning growth and weaning weight, respectively. The literature shows an average of .30 and .24, respectively, for these two traits. Estimates of heritability for weaning weight in adverse range environments and in years when calf weaning weight was considered poor are typically lower than estimates from more favorable environments.

Table 2. Heritabilities of various traits.

Trait	Son-sire regression	Paternal half-sib correlations	Literature
Birth weight	.21	.18	.45
Preweaning gain	.20	.17	.30
Weaning weight	.24	.20	.24
Gain on feed test	.50	.47	.44
168-d test wt.	.54	.42	.47
Carcass wt.	.33	.38	.52
Dressing %	.32	.25	.30
Rib eye area	.01	.51	.40
Rib eye area/unit of carcass wt.	.28	.23	.32
Marbling		.31	.42
Kidney fat		.37	

The heritability of daily gain on test and end of test weight were .49 and .48, respectively. Heritabilities reported in the literature for these traits were very similar. Similarity of heritability for postweaning growth and final test weight in this study of an unselected population with those in the literature where selection for growth rate was practiced indicates the absence of bias in literature estimates due to selection. The agreement in size of heritabilities taken at the end of test weight at approximately 365 d of age and then at slaughter at 450 to 540 d of age would indicate bulls could be selected on weight at any time between these age points with similar accuracy.

Sires and offspring were not slaughtered at the same age in this study so the estimates of heritability calculated by son-sire regression assume a genetic correlation of 1.0 between the same traits measured at different ages. Although the number of sires represented are small (30), these data are supported by the results obtained from correlations among paternal half-sibs.

The heritability estimates for carcass weight averaged .36. This value was lower than the heritability of carcass weight reported by

Table 3. Genetic correlation estimates among growth and carcass traits.[a]

Item	Weaning weight	Daily gain: Birth to wean	Daily gain: On test	Carcass wt.	Ribeye area	Marbling score
Birth wt.	.54	.20	.32	.11	.57	-.18
Final wt.	1.00	1.00	1.00	.98	.71	.19
Carcass wt.	1.00	1.00	1.00	-.-	.80	.38
Dressing %	.01	.16	.36	.32	-.11	.00
Kidney fat, %	.33	.49	.15	.21	.36	.59
Rib eye area	.72	.68	.82	.80	-.-	.51
Marbling score	.81	.89	.19	.38	.51	-.-

[a] Paternal half-sib correlation estimates.

other research workers. Animals in all of the other studies were slaughtered directly from a high growing ration whereas the bulls in this study were slaughtered, in some years, after bulls had been placed on a lower nutritional plane. Whether or not this change in environment affected the estimate of heritability is unknown.

The heritability of rib eye area by the son-sire regression procedure was .01 and is different from the heritability of rib eye area (.51) calculated by the paternal half-sib method, which is comparable to heritabilities reported in the literature for this trait. These results indicate rib eye area of 2-yr-old bulls was not a good indicator of rib eye area of offspring slaughtered at 16 mo of age. Thus, use of ultrasound and other imaging techniques on mature animals may not be useful for predicting carcass merit of their offspring. A more acceptable alternative may be to estimate rib eye areas of potential sires at about 16 months of age.

The estimated heritability of rib eye area per unit of carcass weight was .26. Results would indicate progress could be made by selection for this trait when data are adjusted for carcass weight. Results of this and other studies would indicate carcass traits could be changed by selection if market conditions made it economically feasible to do so.

Genetic Correlations. The genetic correlations among the growth traits in this study nearly all approached 1.00 (Table 3). When selection is made to increase any growth characteristic, other growth traits simultaneously increase. Some other research workers have reported very large genetic correlations among traits indicative of growth potential. Most reports also indicate selection for growth at any time results in growth at other phases of the animal's life. The relationship between growth traits and rib eye area approach .80 which indicate selection for size results in larger rib eye areas. Selection for calves with heavier weaning weights results in carcasses with higher marbling scores. Gain on test, however, had little influence on marbling score which would be expected since rapid gaining animals do not ordinarily carry the most condition at young age.

Conclusions

These results indicate that the heritability estimates being used for growth and carcass traits by the beef cattle industry are useful even though they were calculated on populations selected for growth traits. No major genetic antagonisms appear to exist between growth and carcass traits. Selection for improved carcass merit is expected to simultaneously either not affect growth rate or increase it.

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A GENETIC HISTORY OF LINE 1 HEREFORD CATTLE: 55 YEARS OF SELECTION FOR GROWTH.

M.D. MACNEIL, J.J. URICK, B.W. KNAPP, S. NEWMAN and B. GOLDEN[18]

Introduction

A series of projects to develop lines of beef cattle of superior genetic merit were initiated in 1931. The general goal of these projects was to use inbreeding and selection, in combination, to produce prepotent lines with consistently favorable breeding values for economically important traits. Many of the resulting lines have since been discontinued. However, a line of Hereford cattle designated Line 1 has had a profound influence on the registered Hereford cattle industry (Kuykendall, 1989). In this report we examine components of the genetic history of Line 1 Hereford cattle at the Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana.

Procedures

The Fort Keogh Livestock and Range Research Laboratory is located near Miles City, Montana at an elevation of about 2200 ft above sea level. Annual precipitation averages 13.39 inches with 8.18 inches during the March to July growing season. In January, the average temperature at Miles City is 15 F and in July 73 F. Broken badlands and plains rangelands typical of Eastern Montana and the Northern Great Plains Region support a cow on about 35 acres. The native vegetation has been predominantly western wheatgrass, Sandberg bluegrass, blue grama grass, buffalograss, needle-and-thread, green needle grass, thread leaf sedge and silver and big sagebrush. Annual bromegrasses have become increasingly important in recent years.

Much of the early history of Line 1 Hereford cattle is chronicled in three experiment station bulletins (Knapp et al., 1951; Brinks et al., 1965; and Urick et al. 1966). The description of management practices given here highlights those reported in these earlier reports and provides a brief overview of more recent management of Line 1 at Fort Keogh.

Management practices have remained reasonably constant over the period for 1935 to 1989, with some notable exceptions described below. Cows grazed on native range throughout the year. They are moved to winter pasture around January 1. Varying amounts of protein supplement were fed and hay provided when heavy snow prevented normal grazing. Cows were placed in calving pastures in mid-March. Calving heifers as two-year-olds was initiated in 1977 and the heifers have been calved in lots of about 20 acres since that time. In 1989 cows were calved with the heifers, provided hay during the calving period and cow-calf pairs moved to pasture a few days after birth. Cow-calf pairs were moved from calving pastures to smaller breeding pastures about June 1. A 45- to 60-day breeding season began about July 1 through 1945 and about June 15 thereafter. After the breeding season cows and their calves were moved to rangeland summer pastures. Up to the early 1950's cows and their calves have been gathered about September first of each year. and less promising bull calves were castrated at that time. Since the mid 1970's calves have received preweaning vaccinations for stress induced diseases at the late summer working. Calves were weaned during the week of October 20th at an average age of 180 days. Cows were moved to fall range after weaning.

After weaning, heifer calves were wintered on pasture and fed alfalfa hay to gain approximately 0.5 pounds per day until the winter of 1969-70. These heifers grazed native range and were provided some supplemental feed during their second winter. The heifers were then moved to breeding pastures with the cows and bred to first calve as three-year-olds. From 1970 until 1987 heifer calves continued to be wintered on pasture, but fed to gain 1.0 pound per day. During the winter of 1987-88 and thereafter the heifers were wintered in a feedlot and fed to gain 1.25 pounds per day. Since 1976, yearling heifers have been moved to breeding pastures with the cows and bred to first calve as two-year-olds.

Each fall after weaning male calves were placed on feed. Up to 1944 they were put directly on feed. Since that time the calves have had an adjustment period of about two weeks. Until the late 1950's, the males were fed a mixed ration consisting of 6 parts corn or barley, 3 parts dried molasses beet pulp, 1 part wheat bran, 1 part linseed oil meal and .5 part alfalfa leaf meal with first and second cutting alfalfa hay provided as roughage. Since the mid 1970's a ration consisting of 15% corn, 10% oats, 5% of a 33% protein supplement plus 70% corn silage has been fed. A mixed roughage and concentrate ration formulated to provide about 68% total digestable nutrients was fed in the interum. Diet constituents varied from year to year dependent upon availability. Across all years rations were formulated to result in predicted average growth rates between 2.5 and 2.75 pounds per day. Bull calves were fed for 196 days until 1980 and for 168 days thereafter.

Progeny testing of potential herd sires was initiated in the 1940's. Each candidate for selection was mated to 20 to 30 head of grade Hereford cows. From each progeny group eight steer calves were randomly selected and fed for 252 to 283 days. Management of progeny test steers was similar to that of contemporary bull calves. Bulls that were eventually used in Line 1 were selected from the results of the progeny test until the early 1960's when the basis of selection switched solely to individual performance. Only the faster gaining, heavier bulls were considered as potential herd sires. Conformation of bulls was also evaluated at the end of the feeding period. Some bulls were eliminated based on their conformation or if they were not physically or structurally sound.

[18] The authors are, respectively, Research Geneticist, Research Geneticist (retired), Statistican, Research Geneticist at Fort Keogh Livestock and Range Research Laboratory and Assistant Professor at Colorado State University. Gratefully acknowledged are important contributions by numerous individuals, both named and unmentioned, who have influenced the development of Line 1 Hereford cattle. They include: A.L. Baker, W.H. Black, J.S. Brinks, R.T. Clark, B. Knapp, Jr., A.W. Nordskog, O.F. Pahnish, R.W. Phillips, J.R. Quesenberry, and W.L. Reynolds, F.S. Willson and R.R. Woodward. Bernice Love and Mary Krausz have been responsible for records since the foundation of Line 1.

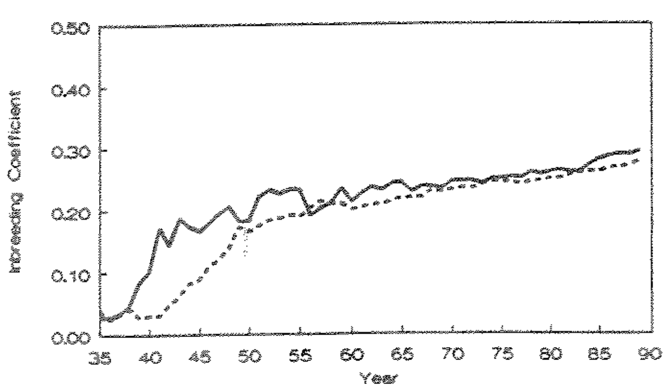
Virtually all calves were weighed within 24 hours of birth and those surviving were weighed at weaning, at 28-day intervals after weaning and at about one year of age. Repeated weights were taken at the beginning and end of the postweaning gain test period. Pre-and postweaning growth rates were calculated from these weights. Best linear unbiased prediction (BLUP) methods for an individual animal model were used to predict direct and maternal breeding values for birth weight and preweaning average daily gain and a direct breeding value for postweaning average daily gain on each of the 5703 straight Line 1 cattle born in the project from 1935 to 1989. BLUP methods properly account for all of the information on individuals and their relatives. The predicted breeding values are adjusted for environmental effects of year, age of dam, sex of calf and for effects of inbreeding of calf and dam which are not transmitted from parent to progeny. Genetic trend is the trend in breeding value over birth years of the calves.

Results

Two half brothers, Advance Domino 20th and Advance Domino 54th are the primary foundation sires of Line 1. Average relationships of all calves born in 1989 to Advance Domino 20th and Advance Domino 54th were 53% and 34%, respectively. Both these sires excelled in growth relative to contemporaries of the era. Mature weights of Advance Domino 20th and Advance Domino 54th were about 1800 and 2000 pounds, respectively.

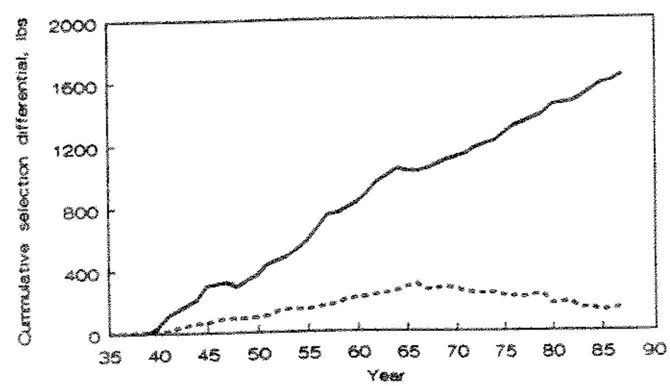
Inbreeding increased rapidly in the late 1930's and early 40's (Figure 1) as a result of mating daughters of each half brother to the other. Since that time inbreeding has increased at a lesser rate that is consistent with some avoidance of matings between close relatives. However, it continues to increase as it must as long as the population remains closed. Inbreeding of the cow herd lags the inbreeding of the calves by one generation.

Figure 1. Inbreeding level of calf (—) and dam (- - -) in Line 1 from 1935 to 1989.



Selected bulls and heifers exceed the average yearling weight of the current year's calf crop. The selection differential for yearling weight measures that superiority for those individuals who actually produce offspring. Illustrated in Figure 2 are the male and female selection differentials accumulated over birth years. As expected, the selection process has continuously resulted in above average bulls being used as sires. However, since the mid-1960's heifers that ultimately became dams appear to have very slightly less than average yearling weights. This is surprising in light of the intended selection for increased postweaning growth potential. A possible explanation is that the range environment in which these cattle produce places an upper limit on the growth potential that also permits reproduction. Also, from the mid-1960's through the 70's cattle were exchanged with a research station at Brooksville, Florida. Very little culling of heifers based on performance occurred during this era and slightly different selection indicies were used. Further investigation of this finding is needed to understand it. On a long term basis bulls contribute far more genetic material to a population than do cows because they potentially leave more progeny. Therefore, continued increases in genetic potential for postweaning growth of the Line 1 Hereford cattle are expected.

Figure 2. Selection applied in Line 1 on male (—) and female (- - -) yearling weights from 1935 to 1989.



The observed trend of breeding values for postweaning average daily gain (Figure 3) is positive, as anticipated. Selection has resulted in breeding values for postweaning daily gain of Line 1 Hereford cattle increasing by .64 pounds per day in 55 years. It is noteworthy that despite 55 years of continuous selection there is no evidence for a plateau in genetic improvement. There continues to be opportunity for selection to increase the genetic potential in postweaning growth rate of Line 1 Hereford cattle. This finding is consistent with selection experiments for increased growth in laboratory animals where genetic improvement remains possible after 30 to 100 plus generations.

All growth traits have some common genetic basis, probably due to the genetic makeup of the animals themselves (termed direct effects by geneticists). Therefore, the usual expectation is that selection for increased weight at one age will lead to increased weight at other ages. Maternal genetic effects provide a less certain impact on this expectation. However, maternal characters which have a genetic component that is transmitted from parent to offspring, like uterine capacity and milk production, are known to affect birth weight and preweaning growth rate.

Figure 3. Genetic trend in postweaning daily gain of Line 1 from 1935 to 1989.

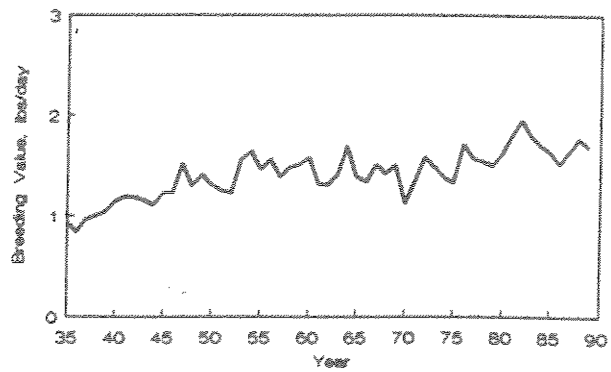
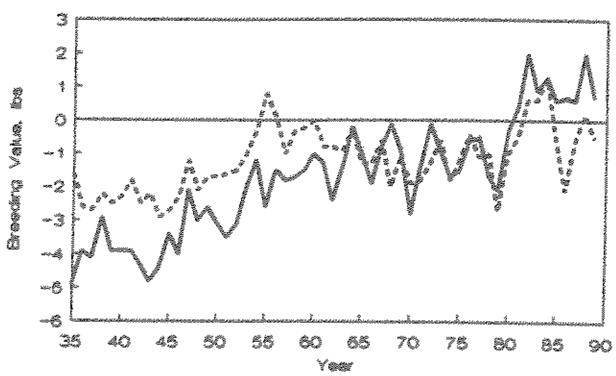


Figure 4. Genetic trends in direct (——) and maternal (- - -) components of birth weight in Line 1 from 1935 to 1989.

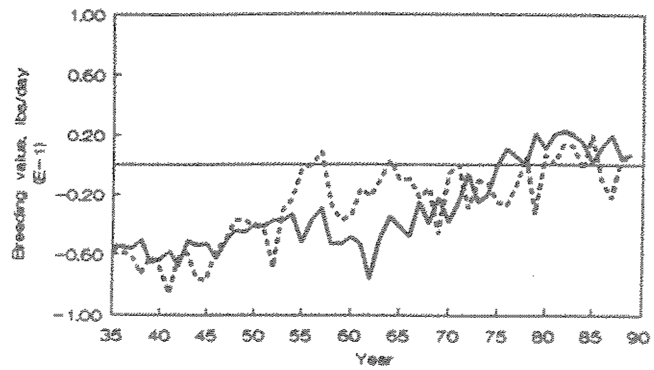


Illustrated in Figure 4 are the trends in direct and maternal breeding values for birth weight of Line 1 Hereford cattle. Both trends are positive. Together they account for approximately a 7 pound genetic increase in birth weight since 1935. About 73% of the genetic increase in birth weight is accounted for by direct effects and 27% by maternal effects.

Direct and maternal effects contribute almost equally to the increase in genetic potential of Line 1 for preweaning growth rate (Figure 5). Thus, while breeding values for growth (potential of calf) and for maternal ability (environment provided by dam) are thought to be antagonistic, improvement was observed in both in the 55 years Line 1 has been a closed breeding population. The total genetic improvement should result in a 32 pound increase in 200-day weight. However, accumulated effects of inbreeding have reduced expression of genetic potential for growth and maternal ability to the extent that the results of selection have been slightly more than offset. This finding need not concern a breeder using Line 1 Hereford bulls to produce outcross calves, because the effects of inbreeding are not transmitted from parent to progeny.

The user of Line 1 seedstock benefits from improved genetic potential for growth resulting from selection while costs of maintaining the inbred line are accrued by the foundation herd at Fort Keogh.

Figure 5. Genetic trends in direct (——) and maternal (- - -) components of daily gain from birth to weaning in Line 1 from 1935 to 1989.



Conclusion

Selection is the only mechanism for making continuous and cummulative genetic improvement. The genetic potential for growth of Line 1 Hereford cattle continues to increase at all ages less than one year. Hereford breeders can benefit by using this seedstock as it may improve genetic potential for growth in some herds. The relatively long and well documented history of the Line 1 breeding program at Fort Keogh Livestock and Range Research Laboratory provides insight for developing organized breeding programs.

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FORT KEOGH LIVESTOCK AND RANGE RESEARCH LABORATORY

Historical Perspective

The Custer Massacre led congress to establish Fort Keogh as an Army cavalry post, July 22, 1876. Fort Keogh was named after Captain Myles Keogh, an adjutant to General George Custer, who was killed in the Battle of the Little Big Horn on June 25, 1876. Establishment and early development of Fort Keogh was under the direction of General Nelson A. Miles for whom Miles City is named. In 1879, Miles City, Montana, was designated the county seat of Custer County and the first court session was held there in May 1879. Both Fort Keogh and Miles City have remained to serve the vast ranching areas of southeastern Montana and the surrounding Northern Great Plains.

In 1907, all infantry troops were withdrawn and in 1909 Fort Keogh became a Remount Station for the U.S. Army. This Remount Station was very active in World War I. During this period, more horses were processed here than at any other army post in the United States. Horses were shipped worldwide. In 1922, the Army relinquished the land and the Fort Keogh military withdrawal was completed on February 2, 1924.

By an Act of Congress dated April 15, 1924 (PL90, 43 Stat. 99) jurisdiction of the Fort Keogh Military Reservation was transferred to the U.S. Department of Agriculture for experiments in stock raising and growing of forage crops. On site remains of the original Fort include the parade ground, a wagon shed built in 1883, the flag pole erected in 1887, and seven other structures built prior to 1924.

The size of the original Fort Keogh Military Reservation was 100 square miles or 64,000 acres. The Fort Keogh Livestock and Range Research Laboratory now occupies about 55,357 acres. In 1878, a large piece of land east of the Tongue River was released by the Army and is now the present site of the City of Miles City. Since that time, additional land has been released for the Miles City industrial sites, Custer County fairgrounds, the warm-water fish hatchery and Spotted Eagle Recreation Area. Approximately 1,800 acres are under irrigation in the Yellowstone River Valley west of the Laboratory headquarters. About 625 acres are in cultivated crops and 1150 in irrigated pastures. The remainder of the laboratory is rough, broken badlands typical of range cattle producing areas of the Northern Great Plains.

The early laboratory, then referred to as a station, was a widely diversified unit. There were approximately 1200 Rambouillet ewes on experiment during the early days. Ewes and lambs were on breeding and feeding experiments and wool studies. All sheep were transferred to the U.S. Sheep Experiment Station, Dubois, Idaho, in 1941.

There was also a Milking Shorthorn dairy herd maintained at the laboratory. The milk was sold to the employees, but the animals were not used extensively for research purposes. The herd was dispersed in the late 1930s.

There have also been many horses on experiments. In 1934, the inventory showed 250 head on breeding, feeding and reproduction studies involving purebred Belgian, Morgan and Thoroughbred sires. Some of the early work to develop successful semen collection and artificial insemination techniques in horses was conducted at this laboratory. The Thoroughbred breeding herd was maintained until 1964. Horses that remain at the laboratory today are used solely for working cattle.

Research on turkeys was also conducted at the laboratory. Studies with Bronze turkeys started in 1929 and involved approximately 1500 young turkeys and 350 breeding hens. Studies consisted of feeding, breeding and rearing experiments, and the original crosses and the early work lead to development of the Beltsville White breed. This line of research was closed out in 1939 when the turkeys were shipped to Beltsville.

Early swine research was directed largely toward production of Wiltshire Sides for the European pork market. In 1930, pork from the U.S. Range Livestock Experiment Station was reported to be the best American Wiltshire Sides on the London market. The swine work is most famous for the development of the Montana No. 1 breed. This was produced by crossing the Danish Landrace and the Black Hampshire breed. Crosses were inbred and through selection, one of the first meat-type breeds was established. Federal funding for swine research at the laboratory was terminated in 1968 and, swine work was then directed by staff members in the Animal and Range Sciences Department at Montana State University. Work involving the Montana No. 1 and the Yorkshire breeds was terminated in 1971 and a crossbred herd was established to supply animals for studies directed by Montana State University nutritionists. The swine research was moved from Fort Keogh to Bozeman in 1986 and the swine unit closed out.

Today, the research program focuses on improving efficiency of beef cattle production for rangeland in the Northern Great Plains. These rangelands, some 150 million acres in Montana, North Dakota, South Dakota and Wyoming, are both ecologically fragile and vital to the economic well-being of the region. The work involves studies in genetics, reproductive physiology, nutrition and growth of beef cattle, and in range pasture development, improvement and management. This mix of disciplines provides an effective and integrated attack on basic and applied problems related to efficient and sustainable use of rangeland resources for livestock production. Emphasis is on problem solving basic research to meet the immediate and future needs of farmers and ranchers in the region and nation. Funding for research is provided by appropriation through USDA-ARS. Cooperation with Montana Agricultural Experiment Station provides livestock and labor resources to the laboratory. No appropriated funds are received from the State of Montana.

Landmark Accomplishments

Research in range improvement and management was initiated at Fort Keogh by the U.S. Forest Service in 1932. Early studies were designed to determine optimum stocking rates for cattle and sheep on Northern Great Plains rangelands. Use of the results from this research by ranchers and Federal agencies took the Plains out of an era of exploitation into one of grazing management. Reduced soil loss, increased plant growth and increased production of both domestic livestock and wild animals has resulted.

Beginning in 1936, water spreading systems were developed by building diversion dams and contour dikes. These studies were among the first in the nation to demonstrate that water normally lost to runoff could be used effectively to increase growth of native and introduced grasses.

Methods for genetic evaluation of beef cattle were pioneered at Fort Keogh in the 1930s. All beef performance testing programs now active in the United States and much of the remainder of the world are built on this foundation. Today's producers continue to benefit from this work as they use estimated breeding values and expected progeny differences to select breeding stock that meets their needs. Success of Line 1 Hereford cattle are proof of the knowledge gained.

The usefulness of crossbreeding to improve the efficiency of beef production was first demonstrated at Miles City in the late 1930s. While it took time for the results to be adapted by the industry as a whole, a look through cattle country today verifies its importance.

Neonatal mortality resulting from calving difficulty continues to be a major source of lost revenue for beef producers. Workers at Miles City first established the role of birth weight as the most important causative factor associated with calving difficulty.

Winters in the Northern Great Plains can be long and cold. Grazing time and forage intake may be reduced by extreme cold and the energy requirements of the cow are increased. Nutrition studies conducted at Fort Keogh have demonstrated the importance of proper winter supplementation regimes for optimum rates of subsequent conception, calf survival and cow and calf weight gains.

Livestock Facilities and Management

Cattle and farming operations at Fort Keogh Livestock and Range Research Laboratory (LARRL) serve to support the research work. Numbers of cattle and production of farm crops are driven by research needs within limits imposed by responsible stewardship of resources. Husbandry practices are designed to meet specific research protocols and the animals' needs as humanely as possible. The farming operation is managed to provide quality feed stuffs for research livestock using proper conservation and agronomic practices.

The research laboratory is located west of Miles City, Montana. The east boundary is the Tongue River and the Yellowstone River crosses from southwest to northeast. There are approximately 1500 acres of improved early spring pastures of crested wheatgrass and Russian Rye. There are approximately 2000 acres of irrigated land in the Yellowstone River Valley. Although acreage may vary according to research needs, approximately 270 acres produce corn for silage, 300 produce alfalfa for hay, 150 are used for small grains and the remainder of the irrigated lands are used as irrigated pasture.

There are two feedlot units at the laboratory, one used for physiology of reproduction research and the other for the genetics, lean beef and nutrition research programs. The physiology program feeds mostly cows and yearling heifers and includes 20 lots, eight with pole sheds. These lots are tied to a large barn with working facilities, including a heated operating room, field laboratory and offices. This barn also serves its original function as a horsebarn. The genetics feedlot consists of 24 lots, 15 of which have pole sheds. These facilities are tied to a quonset type barn that serves as a working facility and sick pen area. The lean beef-nutrition area of this feedlot consists of 13 pens. This entire feedlot area is tied to a large scale house and sort- pen facility. One-half of the scale house serves as a cattle and sheep metabolism area and also houses a sample drying and grinding area. An individual feeding facility is also tied to this scale house area and is being remodeled and upgraded to hold up to 150 animals. The unit will be equipped with electronic identification device actuated, individual gates that are opened only by the animal wearing the specific electronic identification device for that gate. Cattle in the feedlots or being fed individually, generally receive a silage-based ration.

The feedlots are supported by a modern feed mill. The grains are processed by a dry roller mill and stored in an overhead bin cluster that empties directly in to a clam-shell hopper equipped with an electronic scale. This clam shell empties directly into a mixer-feeder truck which weighs and delivers the specific ration to each pen.

There are several remote working facilities that are equipped with a scale building, crowd alley, scale, squeeze chute and sorting pens for working cattle away from the headquarters area.

The rangeland consist of diverse range sites supporting cool and warm season grasses, forbes and shrubs. Cows are divided by age into yearling, 2-year-old and mature cows for fall and winter management are grazed on rangeland year around except during calving or when winter weather prohibits grazing. Cattle are supplemented on winter range with alfalfa or grain pellets and are fed grass or alfalfa hay when not on native winter range. Cows confined during the fall and winter for experimental purposes are fed a silage ration. With the exception of a small fall and winter calving herd, most cows are bred in a 45 to 60 day breeding season beginning around June 15 and calve in April and May. The physiology of reproduction and lean beef herds are artificially inseminated at the AI unit near the Yellowstone River. A 320 acre center pivot irrigator is used with a short duration pasture rotation. The remainder of the cows are bred by natural service in single sire breeding herds held mostly on native range.

Females are palpated for pregnancy in October at weaning. Those cows surplus to research needs and of breeding value in the Line 1, CGC and SCS herds may be selected for the research animal sale. The remaining surplus females will be sold at auction.

Herd Health

Prior to calving all cows are weighed and number brands clipped. During calving all calves are tagged, tattooed, weighed, and measured if required. Following calving all calves are branded, castrated if required, and immunized against seven clostridia types including blackleg and C and D enterotoxemia. Prior to the breeding season, all cows, heifers and breeding bulls are vaccinated for five types of leptospirosis and vibriosis. Following the breeding season, cows, heifers, calves and herd bulls are weighed. Calves are given preweaning shots of IBR-PI_3, 7-way clostridia, BRSV, haemophilus somnus and BVD. Heifer calves are vaccinated for prevention of brucellosis. Calves are weighed and trucked to the feedlots for weaning. All cattle on the station are treated for internal and external parasites in late fall. At weight-on-test in early November, weaned calves are given booster vaccinations for BRSV, haemophilus somnus and BVD.

USDA SCIENTISTS AND STAFF

Dr. Rod Heitschmidt, Research Leader

Diona Austill
Brooke Balsam
Dr. Robert Bellows
Dr. Michael Borman
Janice Clendenen
Ann Darling
Mary Ellen French
Nancy Gilbertson
JoAnne Gresens
Dr. Marshall Haferkamp
JoAnn Hagen
Bradford Knapp
Dr. Michael MacNeil
Cheryl Murphy
Dr. Scott Newman
Dr. Robert Short
Dr. Robert Staigmiller

MONTANA AGRICULTURAL EXPERIMENT STATION RESEARCH ASSOCIATES AND STAFF

Denna Amsden
Bill Anderson
Butch Arnoldt
Eddie Arnoldt
Dick Bonine
Duane Bundy
Alan Charles
Tom Dudley
Paul Dyba
Rick Harris
Ralph Hilderbrand
Jim Howard
Jim Kessler
Mary Krausz
Waine Milmine
Naomi Orestad
Kevin Peterson
Dave Phelps
Alphonse Prevel
Lynn Schied
Andy Shafer
Ken Strobel
Cody Taylor
Mike Woods

HIGHLIGHTS

A decade of range nutrition research leads to more efficient use of feed resources and reduced production costs.

Studies spanning the 1988 drought demonstrate significant plant mortality in crested wheatgrass and Russian wildrye seeded ranges and the need for seeding in some areas to reestablish productive stands.

Grasses adapted to saline-sodic soils differ markedly in palatability and does not provide sufficient energy or protein to sustain growth of livestock as a late summer compliment to native range.

Fertilization and defoliation increase the yield and quality of a bluebunch wheatgrass-quackgrass hybrid that is adapted to saline-sodic soils under irrigation.

Body composition of live cattle is being estimated in a new instrument which measures volume. Condition score provides a useful index of body composition.

Yearling heifers should reach puberty 4 to 6 weeks before the breeding season to maximize conception rate.

Culling heifers for small pelvic areas may reduce the number of cesarean deliveries. Direct selection for large pelvic areas will increase cow and bulls frame size and also calf birth weights.

Nutritional management is the key to minimizing postpartum anestrus and infertility. Other factors such as length of breeding season are also important.

Embryo development in the first weeks after conception is critical to establishing pregnancy. Manipulating embryos provides enhance genotypes and accelerated genetic improvement.

Pine needle abortion is caused by a decrease blood flow to the uterus and cannot be prevented by nutritional variables such as straw, protein, bentonite or mineral supplement.

Developing breeding objectives leads to better selection criteria and genetic progress to maximize profitability of beef production.

Breeds with maximum genetic potentials for growth and milk production may not have maximum productivity as 2-year-old crossbred heifers under range conditions.

Bias due to selection in literature estimates of heritability and genetic correlations was found to be unimportant by comparing those estimates with estimates derived from an unselected herd.

Genetic potential for growth of Line 1 Hereford cattle continues to increase at all ages less than one year, even after 55 years of selection and inbreeding.