Fort Keogh Livestock and Range Research Laboratory

Research & Rangeland Agriculture: Past, Present & Future

1993 Research Report

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

Edited by R.K. Heitschmidt. Fort Keogh Logo designed by S. Newman, D.L. Harris, and J.E. Temple.

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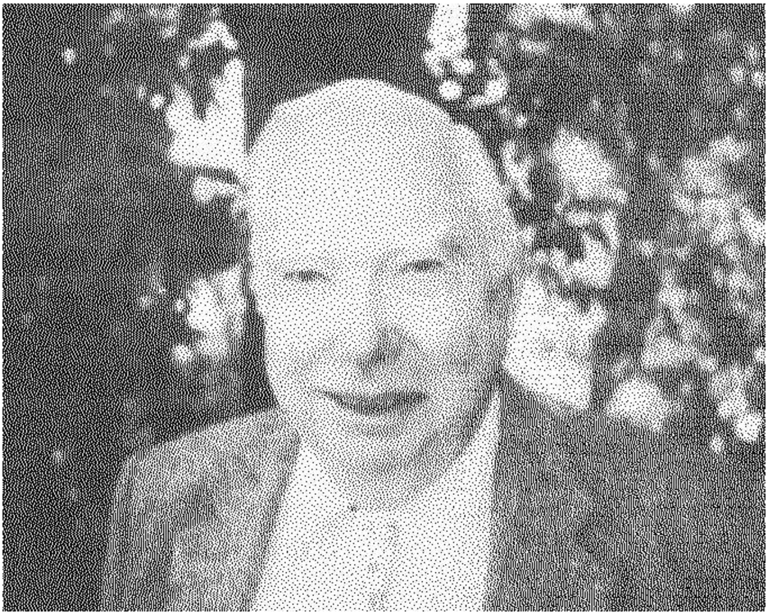
1993 Producer of the Year Awards



A. B. (Buddy) Cobb, Jr.
Augusta, Montana

Biography

Buddy was born August 9, 1920, in Rawlins, Wyoming. He attended grade and high schools in Rawlins, and Cut Bank, Montana. He attended the California Institute of Technology and later graduated from Stanford University in 1941 with a degree in geology. He then entered the U.S. Naval Academy at Annapolis and graduated as an Engineering Officer in 1942. He was on active duty from 1942 to 1946 in the South Pacific and was discharged in 1946.

Buddy returned to the family ranch for a short time and then worked for 5 years in the oil fields from Brazil to Canada. He married Cecile Richardson on March 9, 1950. Following the death of his father in 1951, Buddy and Cecile purchased his father's ranch and went into the ranching business. He purchased his first Charolais bull in 1954 and has maintained an intensive linebreeding program since that time. Initially, Buddy "knew nothing so there was no tradition to break." Working closely with "Scotty" Clark, Ray Woodward, and the Montana Beef Performance Association, he learned to "raise cattle by math." His objective was simply to raise cattle profitably based not solely on what the selling price was, but how cheaply you could produce them. This meant keeping complete records on each animal and selecting on those records. Two important criteria in his breeding program were: 1) It costs too much to raise fat so hold it to a minimum; and 2) Cull any animal that doesn't adapt to the Montana environment. Buddy sells approximately 200 bulls yearly at his famous "silent" auction which eliminates the noise and emotion associated with regular auctions. Any bull that doesn't bring the announced minimum price is loaded on a truck headed for the packing house.

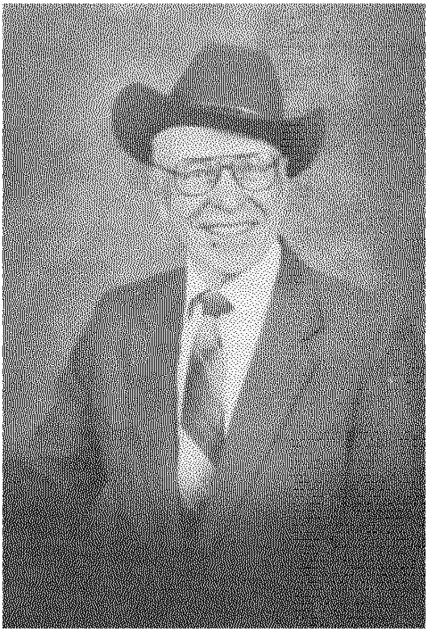
In 1962, Buddy developed a market for young bulls, which were to him the ideal meat animal. Their gains were cheaper to produce and the carcasses were of superior cutability. This beef is marketed as Red Yearling Beef and is sold by Super Save stores in Great Falls, Havre, Helena, and Missoula, Montana. The meat has outsold all other grades of beef because of its superior appeal to the housewife - she is buying more red meat to feed the family.

The breeding - selection program at the AC ranch has had and will continue to have a tremendous influence on beef production both nationally and internationally. Buddy has been a long-time supporter of the research program at the Fort Keogh Livestock and Range Research Laboratory. His long-term support of the young people and 4-H'ers in the Augusta area has had a very positive influence on the lives of many. Buddy has received many awards including being inducted into the American International Charolais Association Hall of Fame, the Dedicatee of the 23rd National Charolais Show, and designated a "Charolais Performance Legend" by Robert de Baca in his book, "Courageous Cattlemen." April 17, 1993, was designated as "Buddy Cobb" day in Montana by Governor Racicot.

Buddy and Cecile celebrated their 43rd wedding anniversary in 1993. They have 4 sons, Burl, John, Mike and Charley. Burl was killed in a horse accident in 1979, and John, Mike, and Charley continue their interests in ranching.

The staff of the Livestock and Range Research Laboratory salutes you, Buddy, for your outstanding contributions and accomplishments to the livestock industry!

1993
PRODUCER RECOGNITION
AWARD



William R. Jones
Choteau, Montana

Biography

Bill was born May 1915 on a Montana pioneer family ranch near Bynum, Montana. His grandfather, W.D. Jones arrived in Montana from Missouri in 1877 at the age of 19 years. He passed the pioneer spirit, and the desire to preserve and to understand the primitive resource of grass and land, on to Bill.

Bill attended Montana State College and finished in 1937 with a degree in Agriculture and majors in Ag Education and Animal Science. After finishing school, he became the Vo-Ag instructor at Huntley Project High School for 10 years. Bill began his long-standing support of Fort Keogh during those years when his livestock judging teams traveled to Miles City and to Fort Keogh. The programs of livestock production and range management were observed and emulated by the F.F.A. boys and "their instructor." Fort Keogh became a focal point not only as a historic outpost, but as a center for information, investigation, and interpretation.

In 1946, the Jones family (Bill, Anita, son David, and daughter Sharon) moved from Worden to an irrigated farm east of Billings. Various enterprises kept them all busy, especially the grade A milk production setup with 40 head of dairy cows. Bill became President of the American Dairy

Association of Montana and represented them at State and National levels and before the Montana Milk Control Board on special occasions. While living at this location, they also became partners in a farm machinery business in Billings and acted as general manager for 2 years.

They moved back to the home ranch at Bynum after 17 years in the Worden-Billings area and found many farming-ranching opportunities in local and regional farm-ranch organizations. In civic efforts, Bill served as county commissioner of Teton County for 6 years, during which he was chairman of the Oil, Gas, and Coal Counties of Montana. A major effort was the development of the Elected County Officials Training Seminar whereby county officials and their deputies were instructed in ways to effectively and efficiently carry out their duties.

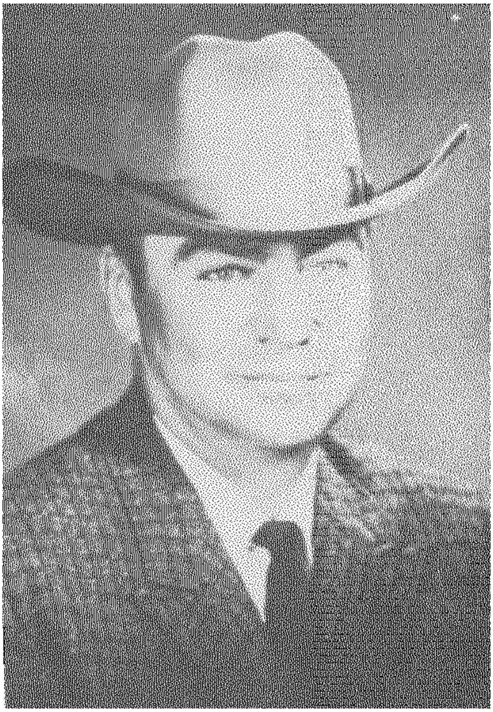
Along with all the other aspects of Bill's busy life, he continued his interest in Fort Keogh. He has demonstrated a deep appreciation for the contribution research makes toward improved methods of production in beef cattle, as well as other phases of agriculture. As an early member of the Montana Stockgrowers Liaison Committee, he was a strong advocate of the reproduction research at Fort Keogh and provided support and encouragement for all phases of research. Truly, he has left his tracks on the Fort Keogh Livestock and Range Research Laboratory.

Over more than 35 years, from 1957 to 1992, probably the most worthwhile "tracks" that Bill left were those upon the lives of more than 40 boys and young men who spent time on the Jones ranch. These boys were from towns and cities all across America. Some were here for summer jobs, others for a year or more, for a school term or a work experience for a college credit. Many were on the verge of being "bad boys" but with lots to do and reward for achievement -- and Anita's good cooking and caring home atmosphere -- not a one crossed the line. They still hear from many of these now successful ranch "alumni."

Presently the major effort is "Reclaiming the Claim." This phrase describes the challenge of bringing abandoned, eroded, weedy, unproductive, cast-off homestead land back to a level of productivity which can sustain a cow and hopefully her owner. In the difficult years before and after the disastrous 1919, many homesteaders in the area adjacent to the "Rocky Mountain Front" had to pull up stakes and leave their claim to the ravages of wind, drought, and over-grazing. Bill is busy "changing the climate," that is the micro-climate on as many acres as he can touch. The demonstration of unprecedented productivity increases spreads ever so slowly to surrounding operations, but they are spreading -- so maybe Bill is leaving some tracks.

Bill is healthy and active -- and living on the ranch and enjoying the "Changing Climate."

1993
PRODUCER RECOGNITION AWARD



Julian Terrett, Jr.
Miles City, Montana

Biography

Julian Terrett, Jr., was born April 3, 1921, in Miles City, Montana; the son of Julian Terrett, Sr., and Marian L. Terrett. He was raised on the family ranch started by his grandfather in 1881. The ranch is located on Beaver Creek in the Northwest corner of Powder River County.

Because of the distance from school, he attended private school at home through the 8th grade and then attended Custer County High School for 2 years. In 1936, his father was appointed Assistant Director of the Grazing Service, and the family moved to Washington, DC, where Julian attended Woodrow Wilson High School for 2 years, graduating in 1939. After working a year, he entered the University of Maryland, majoring in Business Administration. In the middle of his Junior year, Julian was called to active duty with the Army Air Corps. He served in the Air Corps 3 years and was discharged in February 1946, and then returned to the family ranch to work for his father and uncle who were in partnership.

In 1960, with his father and sister, the Terrett Ranch Corporation was formed, and Julian purchased his uncle's interest in the land and cattle.

Julian has been active in agricultural organizations. He served 2 years as President of the Southeastern Montana Livestock Association and was elected to the Board of Directors of the Montana Stockgrowers Association in 1960. Subsequently, he served 2 two-year terms as Director, was elected President in 1972, and reelected in 1973. In 1975-76, he served on the Executive Committee of the American National Cattlemen's Association. During his term as President of MSGA, he was instrumental in forming the Liaison Committee to work with the staff at Fort Keogh and served as chairman for several years. He served 3 terms in the Multiple-use Advisory Council of the BLM, Miles City District, and was elected to the Board of Directors of First National Bank in Miles City in 1970, serving 20 years.

On March 30, 1951, Julian married Ellen Anderson at Miles City. They have 3 children, Julian A., Curtis G., and Nancy Markuson. Julian A. (Jay) married the former Debra Currey of Jordan. They have 3 daughters and live on the family ranch. Curtis married Gayle Roberts of Miles City. They have 2 sons and also live on the family ranch. Nancy married Stan Markuson of Ekalaka, and she is a Math teacher at CCDHS. They have one son and live in Miles City.

The ranch is a cow-calf-yearling operation. The cow herd is straight Angus bred to Hereford bulls. They have purchased black Angus replacement heifers from the same producer for 12 years so the cow herd is all 1 brand. Bulls are turned out June 20. All calves are kept and sold as yearlings. The first-cross, Angus-Hereford heifers are sold as bred heifers and have been purchased by the same producer for 3 years. Additional steer calves are purchased, some being wintered at the ranch, the balance wintered in a growing lot in the Yellowstone Valley east of Miles City. They are normally put on grass April 15 and sold September 20-25; weights at the ranch average 950 -1000 lbs. No farming is done on the ranch except in the process of raising hay. The ranch is watered by springs, wells, and pipe-lines. They have no set system of pasture rotation but try never to graze a pasture until there is adequate forage production and always plan to have some grass on the ground. Pine needle abortion is a definite problem and limits the size of the cow herd.

Rangeland Agriculture in the 21st Century

R.K. Heitschmidt

Introduction

There are many issues that will drive rangeland agriculture into the next century. However, from the broadest of perspectives these issues can be sorted into 4: livestock grazing, environment, sustainability, and profitability.

As an aid to understanding the potential merits and impacts of these issues, a basic understanding of what rangeland agriculture is all about seems appropriate. The objective of this paper is to provide a broad overview of rangeland agriculture as it relates to livestock grazing, environmental concerns, sustainability, and profitability. Hopefully, this overview will provide each reader with another set of ideas that will help him communicate to others the fundamental role that agriculture has previously, is currently, and will continue to play in the fabric of all societies.

The Ecosystem Concept

The ecosystem concept is fundamental to understanding what agriculture generally and rangeland agriculture specifically is all about. An <u>ecosystem</u> is simply an assemblage of organisms and their associated chemical and physical environment. A fishbowl is an ecosystem as is a vegetable garden, a field of corn, a pasture, an entire ranch, the state of Montana, or the United States. In other words, an ecosystem can be essentially anything we want it to be providing we can define its boundaries within which an assemblage of organisms interact.

The structural organization of all ecosystems can be described as consisting of 4 components; 1 non-living and 3 living. The <u>abiotic</u> (i.e., non-living) component defines the chemical and physical environment of the biotic (i.e., living) component. It includes such things as climate, atmosphere, and soils. It is the water in the fishbowl and the soil, air, and sunlight in the garden, cornfield, and pasture.

The <u>biotic</u> component is conveniently subdivided into 3 components; producers, consumers, and decomposers. <u>Producers</u> are organisms that capture solar energy. They are the phytoplankton in the fishbowl, the vegetables in the garden, the corn in the cornfield, and the grasses, forbs, and shrubs growing in the pasture. <u>Consumers</u> are organisms that attain their energy by consuming other organisms. Consumer organisms are animals except in very rare instances (e.g., the Venus fly trap). Consumers that consume plants are called herbivores, those consuming other animals are called carnivores, and those consuming both plants and animals are called omnivores. Cattle are herbivores, coyotes are primarily carnivores, and people are omnivores. <u>Decomposers</u> are the final or last consumers of organic matter. They are the micro-organisms, primarily bacteria and fungi, that complete the decomposition process.

The integrity of an ecosystem is dependent on the efficient flow of energy through the system and the efficient cycling of the raw materials required to capture and process solar energy. <u>Food chains</u> are energy processing pathways that determine the pattern that energy flows through an ecosystem (Fig. 1). There are 2 types of food chains; <u>detrital</u> and <u>grazing</u>. In both chains, the first <u>trophic</u> <u>level</u> consists of the primary producers or green plants. The difference between the chains come at the second trophic level in that if the primary consumers are decomposers, then the food chain is a detrital food chain (e.g., chain #1, Fig. 1), otherwise that defined food chain is called a grazing food chain (e.g., chains #2-4, Fig. 1).

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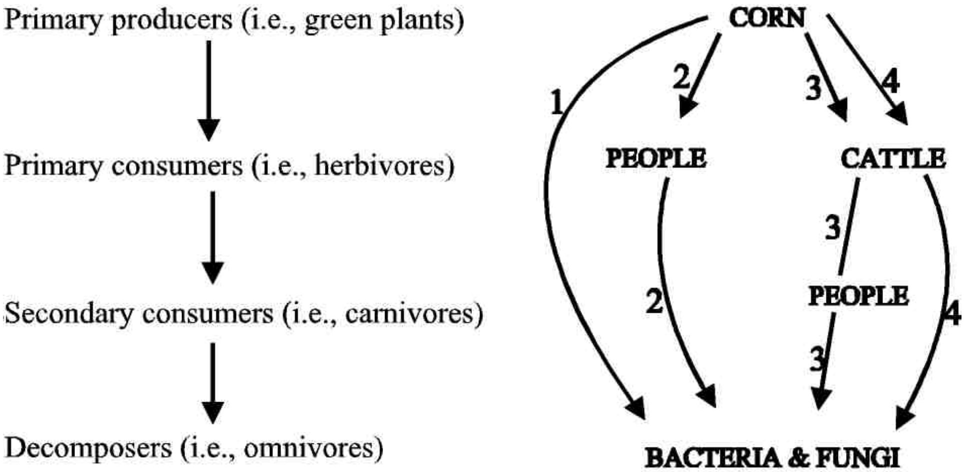

Figure 1. Schematic diagram of potential food chains in a field of corn. Chain 1 is an example of a detrital food chain whereas chains 2, 3, and 4 are examples of grazing food chains.

Regulation of energy flow through an ecosystem via various food chains is governed by the first 2 laws of thermodynamics. In their simplest form, these laws state that although energy can be transformed from one form to another, it can never be created nor destroyed nor can any transformation be 100% efficient. The impact of these laws on energy flow through an ecosystem is that they dictate that the amount of energy that will flow through an ecosystem is set by the primary producers, and that a portion of this energy, usually greater than 90%, will be lost each time the energy is transferred from one trophic level to another. These concepts are depicted in Figure 2 wherein the largest energy store (i.e., box) is the primary producers and the amounts of energy stored in each successive trophic level becomes smaller at every step.

The second indispensable function performed by ecosystems is the cycling of nutrients. Nutrients are the abiotic raw materials required by organisms to capture and process solar energy. Carbon, nitrogen, oxygen, and water are examples of nutrients that are continually cycled by ecosystems (Fig. 3). The cycle revolves around the assimilation of nutrients by the primary producers followed by the sequential reduction of complex organic compounds by consumers to simpler, less complex forms.

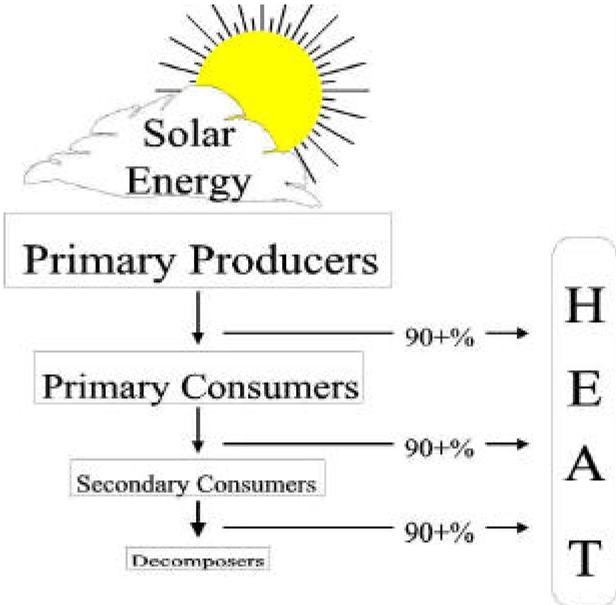

Figure 2. Simplified illustration of energy flow through a 4 trophic level food chain. The 90+% loss of energy at each step is a reflection of the energy required to simply maintain organisms (i.e., no growth).

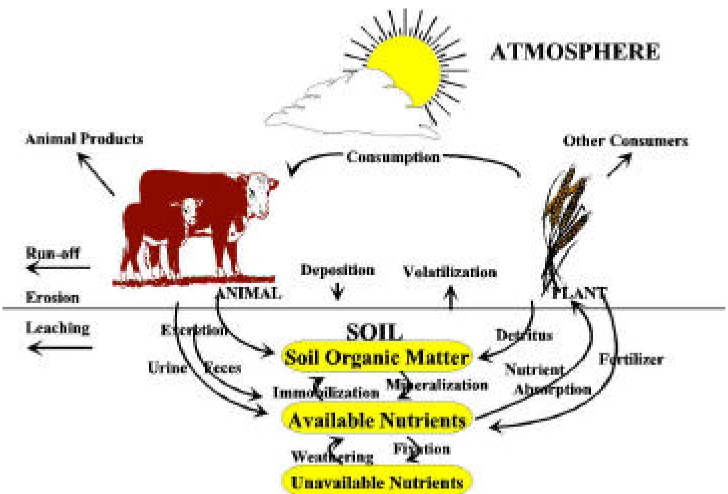

Figure 3. Simplified illustration of nutrient cycling within an ecosystem.

The Ecosystem Concept and Agriculture

Agriculture is traditionally defined as the business of producing food and fiber. But a basic understanding of the structure and function of ecosystems reveals that agriculture can be defined also as the business of capturing solar energy and transferring it to people for their use. It can be reasoned then that success in agriculture is closely linked to the employment of management tactics that either enhance the efficiency that solar energy is captured and/or the efficiency that captured solar energy is harvested and/or the efficiency that harvested solar energy is assimilated. Examples of management practices attempting to improve the efficiency that solar energy is captured, harvested, and assimilated are numerous. For example, common tactics utilized to enhance efficiency of solar energy capture are irrigation, fertilization, and the planting of hybrid seeds. Two examples of tactics used to improve the efficiency whereby captured solar energy is harvested are the use of insecticides and livestock grazing of post-harvest residue. In these instances, the insecticides are employed to shift the flow of captured solar energy from food chains that do not include people (e.g., rangeland forage ? grasshoppers ? decomposer) to those that do include people (e.g., rangeland forage ? livestock ? humankind ? decomposer). This shift is achieved by simply eliminating the competing consumer. Likewise, livestock grazing of post-harvest residue works in a similar fashion in that it shifts the flow of energy from a detrital food chain (e.g., corn stalks ? decomposers) to a grazing food chain that includes people (e.g., corn stalks ? livestock ? humankind ? decomposers).

Similarly, many different types of tactics are employed to improve the efficiency whereby harvested solar energy is assimilated. Two tactics commonly used to directly enhance assimilation efficiency are the feeding of mineral supplements and doctoring sick animals. Often feeding just a small amount of a deficient nutrient or vaccinating to eliminate disease will dramatically improve an animal's performance. But the most common management tactics employed to increase assimilation efficiencies are tactics that alter quality of foodstuff. In fact, food quality can be defined strictly by its relative effect on assimilation efficiencies in that high and low quality foods are those that result in high and low net energy gains to the consuming organisms. For example, rangeland forages are deemed low quality human foodstuff and high quality ruminant livestock feedstuff. The reason for this disparity is that ruminant digestive systems are such that they can process range forages in a manner whereby they can derive most of their life giving nutrients from the forage. This is in contrast to humankind digestive systems which are incapable of effectively digesting these same forages. Thus, the assimilation efficiency of range forages is low for humankind and high for ruminants.

Even the efficient production of fiber (e.g., cotton, timber, and wool) is dependent on the efficient capture of solar energy and its subsequent harvest. That is why cotton, for example, is often irrigated and fertilized (i.e., increase efficiency of solar energy capture). But in contrast to food production practices, post-harvest processing of fibers is designed primarily to interrupt food chains and prevent consumption of the fiber (e.g., termites consuming wood).

Rangeland Agriculture in the 21st Century - The Issues

Grazing. Based on a fundamental understanding of how ecosystems function, it is readily apparent that grazing of rangelands by large herbivores is rangeland agriculture. This is so because without grazing only a small portion of the solar energy captured by rangeland plants can be effectively harvested and assimilated by people. People are effective berry pickers, but they are not effective grazers of rangeland forages. Ruminant animals on the other hand, are effective grazers and as such they are the backbone of rangeland agriculture. Quite simply, ruminant herbivores are the "energy brokers" of rangeland agriculture for without them most of the solar energy captured by rangeland plants would pass through food chains devoid of people. Therefore, without ruminant livestock grazing rangelands, a large portion of the solar energy captured by the world's green plants would not go towards feeding and clothing people.

The importance of rangeland agriculture is difficult to estimate on a world-wide basis. However, because about 50% of the world's land area is rangeland, there is little doubt that rangeland agriculture makes an enormous contribution to the feeding and clothing of the world's people. More specifically, it is estimated that 50% of the foodstuff consumed by beef cattle in the U.S. come from rangeland forages. Thus, on an annual basis, at least $20 billion of the $40 billion U.S. beef cattle industry can be directly attributed to rangeland agriculture.

Environment. The environmental consequences of rangeland agriculture will also continue to be a driving issue in the 21st century, as they should be. The issue centers around what the long-term consequences of rangeland and other forms of agriculture are on the biotic and abiotic components of ecosystems. This is an important and researchable question, and we must continue to diligently seek answers to the questions at hand. A basic understanding of how ecosystems function and what agriculture is all about simply provides greater impetus for our efforts.

Sustainability. Sustainability of rangeland resources will continue to be a leading issue into the 21st century. It is an important issue and must be continually considered in all our management plans.

A fundamental problem with the questions associated with sustainability stems from our failure to clearly define what sustainability is or what it is not. The ecosystems concept provides one vessel that can help in our understanding of what sustainable agriculture is all about. <u>Sustainable agriculture</u> may be broadly defined as ecologically sound agriculture or narrowly defined as eternal agriculture, that is, agriculture that can be practiced continually for eternity. Now with those thoughts in mind, what form of agriculture is more sustainable than rangeland agriculture? The answer quite obviously is that no form of agriculture is more sustainable than properly managed rangeland agriculture because no other form of agriculture is less dependent on external finite resources, such as fossil fuels, and/or external, potentially environmentally sensitive resources such as fertilizers, pesticides, etc. The point is - rangeland agriculture was being practiced long before humankind inhabited this earth, and there is every reason to believe grazing of rangelands by large herbivores will continue to go on to eternity with or without humankind's management expertise.

But the issue of sustainable agriculture goes beyond the idea that it is eternal agriculture because without the use of fossil fuels in agriculture, it is not possible for agriculturalists to feed and clothe the world's human population. Fossil fuel technology is a major reason that agriculturalists can produce an abundance of food and fiber. This is reflected in Table 1 which shows that as fertilizers, etc. (i.e., fossil fuels) are increased, yields increase. Unfortunately, these data also reveal that the efficiency of production, as measured by energy output/input ratios, decreases as yields increase; and therein lies the dilemma. So what is the issue of sustainable agriculture all about? It is about the issue of how we can maintain high yields of agricultural products while maintaining high levels of ecological efficiencies. The challenge to agricultural scientists is to develop the technology that will allow us to maintain and/or increase product yields while increasing ecological efficiencies, and it is a challenge that we at Fort Keogh welcome.

Table 1. Efficiency of corn production in Mexico using only manpower (i.e., organic gardening) and in the United States using modern farming practices such as adding fertilizer, spraying for insects, irrigating, etc. (from Pimentel 1984).

	Mexico	United States
Energy inputs (kcal/ac)	224,161	3,397,064
Yield		
(bushels/ac)	31	112
(kcal/ac)	2,794,008	9,910,028
Efficiency (output/input)	12.5	2.9

Profitability. Certainly, profitability will continue to be a major issue in rangeland agriculture in the 21st century. But it is important we recognize that profitability is a social rather than a biological issue similar to the grazing, environment, and sustainability issues. Moreover, it is important that we recognize that there is a vast array of other social issues that will impact the profitability of rangeland agriculture in the 21st century. Two prime examples of such issues are the red meat dietary quality and animal welfare issues. These issues are not going to disappear. But it is important that we understand that ecosystems do not function in accordance with the "social" laws of the land; rather ecosystems function in accordance with the physical, biological, and chemical laws of nature. Based upon the basic ecosystem concepts presented earlier, it is readily apparent that the challenge to the managers of all natural resources is to employ management strategies and tactics that are not only economically (i.e., profitable) sound, but also ecologically (i.e., sustainable) sound, and that is why the stated mission of the Fort Keogh staff is to develop new and innovative range livestock production systems that are both ecologically (i.e., sustainable) and economically (i.e., profitable) sound.

Genetics Research at Fort Keogh: A Historical Perspective

S. Newman

Introduction

> *"At what point in the history of mankind did human beings first become aware of problems of heredity and of the transmission of features and characters from one generation to another? We do not know. We can assume, however, that conscious or unconscious selection of characters first occurred during the prehistoric period of transition from hunting and food gathering to tillage and animal husbandry."*
> *Stubbe, History of Genetics, 1972.*

Foundations of modern livestock improvement extend back to the mid-1700's, when Robert Bakewell began his animal breeding work at Dishley, England. He had definite "ideals" for selection of beef cattle, e.g., a low-set, blocky, quick-maturing animal almost unknown at that time. He bred best to best regardless of relationship, which often meant rather close inbreeding.

Modern animal breeding is built upon the work of Bakewell in the sense that: 1) it is of primary importance to define a goal or objective in a breeding program; and 2) measures of genetic merit like expected progeny differences (EPD's) account for all performance information from relatives. Since its inception in 1924, Fort Keogh Livestock and Range Research Laboratory (LARRL) has been a leader in development of tools for genetic improvement that enhance the accuracy with which we choose superior breeding stock. Beef cattle have been emphasized to a greater extent than other livestock species at Fort Keogh. Recurring themes in research over the last 70 years include combined effects of inbreeding and selection on performance in turkeys, swine, and beef cattle; foundations of performance testing in beef cattle; and crossbreeding in swine and beef cattle.

Although LARRL is expressly involved in research with beef cattle at the present time, that was not the case at its inception. In 1927, the animal inventory for LARRL included:

"... A purebred Belgian Stallion with 49 pure-bred and draft horses, one purebred Morgan stallion, and one thoroughbred stallion with 26 purebred Morgan mares and 46 grade mares and geldings of saddle type; 250 purebred Hereford cattle; 2,000 grade and purebred Rambouillet sheep; and 44 head of breeding hogs representing Duroc Jersey, Chester White and Yorkshire Breeds."

Turkeys were brought to LARRL in 1929. A Milking Shorthorn dairy herd was maintained beginning in the early 1930's. The milk was sold to the employees, but the animals were not used extensively for research purposes. The herd was dispersed in the late 1930's.

What follows is a brief description of research pertaining to genetic improvement in the various species of livestock that maintained residence at LARRL. Readers are encouraged to inquire about printed records of these investigations, many of which are maintained in the Fort Keogh Library.

Turkey Improvement Programs

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. The only breeding research alluded to in a 1935 Research Report stated that:

> *"Turkey breeding experiments resulted in a simple, easily operated plan for maintaining the average egg weight and improving the fertility and hatchability of eggs and egg production."*

An article that appeared in the 1931 Yearbook of Agriculture reported that these improvements were due to both modern methods of sanitation and to genetic improvement. A project to study effects of inbreeding on genetic improvement of turkeys began in 1931 and was terminated in 1935. Outbred (non-inbred) matings were maintained to affect adequate comparison of the effects of inbreeding. General conclusions were: 1) mild (inbreeding = .125 to .218) and close (.25 to .411) inbreeding had little effect on fertility, egg production, and egg weight when compared to outbred matings; 2) mild and close inbreeding had an adverse effect on hatchability; and 3) intense inbreeding (.5 to .672) affected fertility and hatchability of eggs but had a slight effect on production and average egg weight.

Turkey research was terminated in 1939 when the turkeys were shipped to ARS Headquarters in Beltsville, Maryland. The original crosses produced at Fort Keogh led to development of the Beltsville White breed, the first meat-type turkey breed developed in the US.

Sheep Improvement Programs

Sheep research at Fort Keogh centered around nutrition studies such as winter supplementation, pre- and post-lambing feeding regimes, and alternative protein and energy supplementation. Individual measures of fleece weights, fineness scores, character, staple length, and density were recorded to determine relations between methods of feeding and management on increasing the yield and quality of wool. There is no record of sheep breeding experiments taking place at LARRL. The only mention of genetic improvement came in a 1935 research report:

> *"During the 11 years these sheep investigations were in progress at the U.S. Range Livestock Experiment Station, all rams used in the breeding work were bred by the Bureau of Animal Industry and furnished from the U.S. Sheep Experiment Station, Dubois, Idaho. The Rambouillet rams were all purebreds and were selected for freedom from excess skin folds and for heavy fleeces of wool having a good length of staple. As a result of several years of progeny testing and selective breeding, there was developed a band of uniform, smooth-bodied Rambouillets, especially useful for breeding experiments and grazing investigations."*

All sheep at LARRL were transferred to the U.S. Sheep Experiment Station in 1941.

Equine Improvement Programs

In 1912, Fort Keogh became a remount post for the U.S. Army. More horses were processed through Fort Keogh than any other post in the country. In 1925, after establishment of the Range Livestock Experiment Station, the second Government Morgan Horse breeding program was founded (the first was established in Middlebury, Vermont). Between 1925 and 1935, LARRL produced 93 purebred Morgans, 77 Morgan-grade crosses, and one Morgan-draft horse. Draft horses and thoroughbreds were raised at the station as well. Morgan x thoroughbred crosses were considered the "ultimate cow horse" at the time because it combined the stronger legs of the thoroughbred (for covering long distances in a day) with the easy upkeep of the Morgans, which

didn't tire as quickly.
Horses were primarily used at LARRL to perform the necessary work at the Station. Thus, experimental studies were made to fit into this situation. Much of the early pioneering work in development of semen collection and artificial insemination techniques took place at Fort Keogh until the early 1940's.

The breeding of draft horses at LARRL amply demonstrated the importance of selecting suitable sires in producing horses adapted for use on the Northern Great Plains. For example, a research summary from 1945 reported that:

> *"The Belgian sire 'Rowdy' showed unusual ability in transmitting to his progeny (a) uniformity; (b) desirable temperament; (c) draft confirmation; (d) desired shape and soundness of feet and legs; and (e) straight balanced action even though the mares used differed greatly in type, breeding, and quality."*

The Morgan stud was slowly dispersed after 1935. It is not known what happened to the Belgian horses. The thoroughbred breeding herd was maintained until 1964. The Laboratory now has a herd of about 20 horses that are used exclusively for working cattle.

Swine Improvement Programs

Experimental work with swine at LARRL began in 1925. Initial studies were nutrition-based (e.g., barley vs corn for fattening pigs). Animals used in these studies were crosses between Yorkshires and Chester Whites. In late fall of 1935, the entire swine herd was liquidated and in 1936 foundation herds of Danish Landrace and black (beltless) Hampshires were established with animals from the Agricultural Experiment Station, Beltsville, Maryland. Thus began one of the first composite breed development studies in the U.S., as the objective of the study was to *"...combine genetically the best traits of each of these breeds into a single strain of the same color as the black parent strain of the Hampshires."* Different intensities of inbreeding, in combination with selection of progeny were used to *"fix characters such as prolificacy, economy of production and conformation."*

Landrace white color proved to be dominant over the Hampshire black. Thus, F_1 animals were inter-mated and backcrossed to Hampshire to produce black pigs for future generations. A recessive gene for spotting was detected in 1945. It is interesting to note that no selection for performance was begun until the spotting factor was eliminated although initial estimates of crossbred superiority proved promising. Due to limited resources, breeding herds of this black strain were established at Montana State University, Oregon State University, and the University of Nebraska. In spring of 1947, the name of "Hamprace" was adopted for this new breed of hogs. The Inbred Livestock Registry Association renamed this breed Montana No. 1 in 1948 from its geographic origin and numerical order of adoption as a breed.

A 1957 USDA Bulletin (no. 528) reported development, characteristics, performance, and distribution of Montana No. 1. Six one-sire lines and one two-sire line were developed between 1936 and 1954. Due to high inbreeding, some lines were lost. Inter-crossing of remaining lines occurred in 1951. Cumulative selection differentials (the annual superiority of selected individuals over those available for selection) were .34 for number of pigs farrowed per litter, .42 for number of pigs weaned per litter, 13.8 lbs for litter weight at weaning, and 1.8 lbs for individual weight at weaning. Feed lot performance (record-of-performance) was measured from 1942 to establish postweaning gain differences. Slaughter data was also collected. Live backfat measurements were first taken in 1956.

In 1953, an experiment was initiated to test the usefulness of *reciprocal recurrent selection (RRS),* a breeding program that allowed the selection of boars based upon combined purebred and crossbred performance. This type of breeding system had been used successfully by corn breeders in the development of improved hybrid corn varieties. In RRS, randomly selected individuals from two lines or breeds are progeny tested in crosses with each other. Those individuals of each breed having the best cross progeny were then inter-mated to perpetuate their respective breeds. Offspring from these within-strain matings were again progeny tested in crosses with the other and the cycle repeated. Montana No. 1 and Yorkshire breeds took part in this test. The project ended in 1963. General conclusions were that there was some decrease in fertility and increase in growth rate in Montana No. 1 due to RRS. The two cross-line groups were intermediate to the inbred lines for most traits studied.

Federal funding for swine research at LARRL terminated in 1968. Work involving Montana No. 1 and the Yorkshire breeds was terminated in 1971 and a crossbred herd was established to supply animals for studies directed by MSU nutritionists. The last of the swine research unit was moved to Bozeman in 1986.

Beef Cattle Improvement Programs

According to a 1927 research report:

> *"A herd of registered Hereford cattle was purchased by the State of Montana on November 1, 1924, from George Miles and Sons, Miles City, as a foundation for range beef cattle operations. This herd comprised 96 breeding cows, 19 yearling heifers, 69 calves, and 4 herd bulls."*

During this period, corn breeders were achieving great success in developing hybrid corn varieties that out-produced their inbred parents. In livestock, crossbreeding was the antithesis of acceptable production practices. Thus, the objective of initial research was the development of inbred lines of Hereford cattle particularly adapted to range conditions. Selection within each line was based upon performance rather than subjective visual standards. Fertility, rapid and economical gain, conformation, and high dressing percentages were the major traits of importance in the breeding programs. Development of these lines began at LARRL in 1934. By 1945, 3 lines were either established or just underway; in total 14 lines were developed by 1957.

Linebreeding program. Beginning in 1935, methods of genetic evaluation of beef cattle were pioneered at LARRL. All beef performance testing programs now active in the U.S. and much of the remainder of the world are built on this foundation. The concept of progeny testing steers of promising sires and lines of breeding was established. Individuals were stall fed postweaning. Progeny groups differed in weaning weight, postweaning gain, feed efficiency, and dressing percentage! This led, in 1946, to computing the first heritability estimates for performance traits in beef cattle, and established the separation of the influence of heredity and environment on performance. In general, it was concluded that much improvement could be expected from selection for growth rate, weight for age, and carcass quality, but only little improvement may be expected from selection for higher dressing percentage. As early as 1954, researchers at LARRL were recommending use of low birth weight bulls on yearling heifers, based upon studies of genetic variability (differences in sire groups) of birth weight. The determination that traits of economic importance were rather highly heritable changed beef cattle selection from visual appraisal to performance standards and affected cattle breeding more than any other event in its history.

Use of ultrasound for live animal evaluation of fat and lean tissue began in 1960 when LARRL embarked on a study to improve beef carcasses through more accurate live animal evaluation. Bulls were chosen from feedlot tests based upon a selection index that included weight for day of age and fat thickness. Remaining yearling bulls were slaughtered for carcass appraisal. The conclusion was that selection index was ineffective in applying selection pressure against fat thickness, although interpretation of the data was limited due to the small numbers (387) of animals sampled.

All inbred lines developed at LARRL other than Lines 1, 2, and 3 were established by purchasing related bulls and heifers from individual herds. Each line was maintained as a closed herd with no outside introductions. Sire selection was based almost exclusively on performance testing for postweaning growth. By 1962, six of 11 lines had been culled for poor growth or other problems. At this time, line crosses were made among five of the lines, based upon success of previous crosses, which showed line-cross progeny expressing heterosis through growth traits. Of the 14 lines that were eventually produced, only Line 1 exists today, and is undoubtedly the longest-running beef cattle selection experiment in the world. In a recent publication (MacNeil et al., 1992. J. Anim. Sci. 70:723-733), data from 1934 to 1989 was summarized in terms of estimated breeding values (EBV's; expected progeny differences, EPD's are one-half the EBV), which takes into account performance and pedigrees of all animals used in the line. For example, the graph below displays the genetic trend in yearling weight in Line 1. It is obvious that there has been a steady increase in yearling weight since 1934.

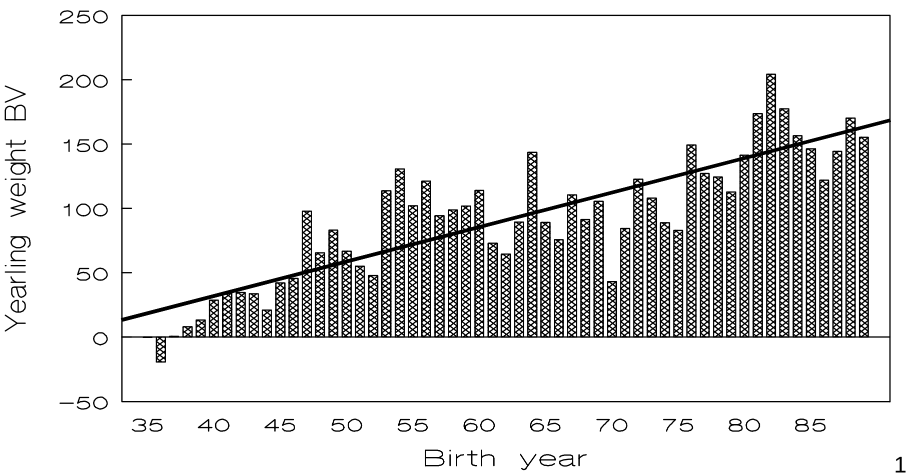

Figure 1. Genetic trend in yearling weight of Line 1 Hereford cattle at Fort Keogh.

The building blocks of performance recording that were established so early in the beef cattle industry obviously have had a profound influence on genetic improvement of all livestock. This could never have been achieved were it not for the foresight of past researchers, who developed and refined performance recording techniques currently with the development of inbred lines of cattle. It is interesting to note that by 1983, almost 68% of all purebred Hereford calves produced in the U.S. have some Line 1 breeding in their pedigrees.

In 1961, researchers at LARRL were interested in knowing to what extent adaptation to a specific location or environment influenced the productivity and efficiency of beef cattle production. Thus, a study of genotype x environment interaction was begun between LARRL and the Subtropical Research Station at Brookesville, Florida, with the shipment of 65 Line 1 cattle. The herd was treated as a closed line at each location. A herd originating in Florida was also formed where females were mated to bulls of that line. One-half of the Florida herd was transferred to Montana concurrently with the shipment of Line 1 cattle to Florida. Thus, two herds existed that were selected for performance at both locations. It was concluded that cattle of Montana origin performed best in Montana and cattle of Florida origin performed best in Florida. Thus, each group of cattle was better suited genetically to their location of origin. The project ended about 1974.

From 1976 to 1988, a herd of cross-line Herefords was managed under a random selection procedure (the Selection Criteria Study, or SCS). The purpose was to examine as many growth and reproduction measurements as possible to determine direct and correlated effects of selection. This was unique in that most herds where genetic parameters were estimated had some previous history of selection, thereby potentially biassing the estimates obtained. With new techniques of variance component estimation, selection history can be accounted for when analyzing such data. Data from this experiment are now being analyzed using these new and more accurate and unbiased techniques.

In 1978, a new selection experiment began with Line 1 addressing concerns among beef producers over calving difficulty. The herd was "sub-lined" into two herds. Replacement sires in the Y sub-line were selected for high yearling weight. In the YB subline, independent culling levels are used where average or below average birth weight of sires is an additional selection criterion. This project ends with information collected from the 1993 calf crop.

Crossbreeding program. Breeding experiments involving a three-way cross of Hereford, Shorthorn, and Aberdeen Angus cattle were started in the 1938 breeding season when two groups of randomly selected Hereford cows were bred to Shorthorn bulls. This continued through 1939; Angus bulls were used on crossbred females from 1941 to 1942. Preliminary results showed that crossbred animals exceeded purebred animals in growth and carcass merit, and that three-way cross animals exceeded F_1's. It is interesting to note that in a 1944 research report it was stated, *"The use of crossbreeding has been criticized because of the belief that it would not be advisable to use the crossbred females for calf production."* By 1959, performance testing had also included Charolais sires. Performance testing of steers included Charolais, Brown Swiss, and Brown Swiss x Hereford.

In 1961, a long-term crossbreeding project began by mating Hereford, Angus, and Charolais sires to Hereford, Angus, Charolais, and Brown Swiss dams. The first progeny from this phase were born in 1962 and the last in 1965. Rotational crossing among these breeds occurred at this time. The project ended in 1976. General conclusions supported the notion that two- and three-way rotational crossing schemes were useful in that they provided their own crossbred female replacements. The three-way system produced higher levels of heterosis than two-way.

With an increased influx of new breeds to the U.S., LARRL instituted a new project in 1974 to evaluate Angus, Red Poll, Pinzgauer, and Simmental breeds. Again, this project included an objective related to genotype x environment interaction. Sires used at Miles City were also used in the Germplasm Evaluation program at the U.S. Meat Animal Research Center, Clay Center, Nebraska. These breeds were chosen based on size of sire breed (medium or large) and level of milk production (medium or high) to provide a more general level of applicability of the results than inference to the breeds alone would allow. In 1977, a group of Hereford x Tarentaise females was added, and Tarentaise sires were included as a sire breed.

In 1979, a project was started at LARRL to develop a composite of beef breeds adapted to the Northern Great Plains. Red Angus females were mated to either Charolais or Tarentaise sires. Subsequent crossing of foundation animals produced a composite population that is **2** Red Angus, **3** Charolais, and **3** Tarentaise. Analysis of the population to 1990 showed the herd to be well suited to the range environment, with high pregnancy and calving rates, fast gains, and acceptable carcass quality. In 1988, three lines were formed, reflecting two different methods of selection for biological efficiency plus a control line. In one line, bulls are selected on the index I = yearling weight - 3.2(birth weight). This index accounts for potential losses due to calving difficulty from heavier birth weights of calves, while in theory minimizing effects on growth. In the second line, bulls are selected on an index I = weaning weight/cow weight, resulting in a measure of production per unit of cow size. This index has been advocated as a measure of biological efficiency in terms of maternal productivity, assuming annual feed requirement is related to cow weight. The final calf crop of this study will be in 1994.

The Future

Recent collaborations with groups in Canada and New Zealand have led to a greater understanding of the development of breeding objectives and selection indices that optimize profit of beef cattle production. Research continues in testing the accuracy of genetic evaluation procedures, investigating sources of bias (e.g., inbreeding) in EPD's, understanding genetic antagonisms between biological traits and their effects on multiple-trait selection, and exploiting dominance effects in breeding programs. Just as researchers at LARRL first developed the foundations of performance recording for genetic evaluation, LARRL geneticists are cooperating with other locations in defining variability of DNA sequences that may lead to eventual discovery of major genes affecting traits of economic importance. The genetics program at Fort Keogh will remain a vital force in the development and application of techniques that improve beef cattle production.

Key Individuals Associated With the Genetics Program at Fort Keogh

Individual	Years at Fort Keogh	Position
R.E. Hutton	1925 - 1951	Swine Geneticist
A.L. Baker	1925 - ?	Beef Cattle Geneticist
J.R. Quesenberry	1926 - 1961	Beef Cattle Superintendent
B. Love	1926 - 1962	Records Clerk
N.A. Jacobson	1934 - 1946; 1949 - 1971	Beef Cattle Extension Specialist
E.P. Orcutt	1937 - 1961	Beef Cattle Geneticist
R.T. Clark	1938 - 1945	Beef Cattle Geneticist
B. Knapp, Jr.	1942 - 1952	Beef Cattle Geneticist
F.S. Willson	1946 - 1956	Beef Cattle Geneticist
R.R. Woodward	1946 - 1960; 1976 - 1979	Beef Cattle Geneticist
A.E. Flower	1948 - 1973	Beef Cattle Geneticist
C.E. Shelby	1950's	Beef Cattle Geneticist
C.O. Miller	1951 - ?	Swine Superintendent
F.J. Rice	1956 - 1960	Beef Cattle Geneticist
N.M. Kieffer	1959 - 1964	Beef Cattle Geneticist
M. Krausz	1960 - 1993	Records Clerk
J.S. Brinks	1960 - 1967	Beef Cattle Geneticist
J.J. Urick	1961 - 1990	Beef Cattle Geneticist
O.F. Pahnish	1964 - 1983	Beef Cattle Geneticist
E. Krehbiel	1964 - 1969	Swine Superintendent
R.L. Blackwell	1966 - 1987	Beef Cattle Geneticist
W.L. Reynolds	1977 - 1990	Beef Cattle Geneticist
B.W. Knapp	1979 - present	Beef Cattle Statistician
T.C. Nelsen	1982 - 1986	Beef Cattle Geneticist
M.D. MacNeil	1989 - present	Beef Cattle Geneticist
S. Newman	1990 - present	Beef Cattle Geneticist
Current Genetics Research Support Staff		
W. Milmine	1968 - present	Assistant to Superintendent
A. Shafer	1970 - 1993	Feedlot
C. Taylor	1972 - present	Cow Crew
J. Kessler	1973 - present	Cow Crew
A. Arnoldt	1974 - present	Feedlot
T. Dudley	1979 - present	Cow Crew
T. Mott	1991 - present	Genetics Crew Supervisor

Restricting Birth Weight and Increasing Growth in Line 1 Hereford Cattle

M.D. MacNeil

Introduction

The incidence and severity of calving difficulty increases as calf birth weight becomes excessive. Increased likelihood of calf mortality and delayed rebreeding of cows are consequences of calving difficulty. Thus, excessive birth weight may be a root cause of reduced income to cow-calf producers.

Taken out of context, a solution to excessive birth weight is quite simple. Birth weight is easily measured and highly heritable. Therefore, selection favoring low birth weight would be effective. However, high birth weight is also genetically correlated with subsequent rapid growth. Thus, there is a dilemma. Can cattle be selected to reduce the genetic increase in birth weight while still allowing genetic potential for growth to increase? The following study, which began in 1978, was conducted to explore breeding strategies addressing this dilemma.

Methods

Two sublines of Line 1 Hereford cattle have been maintained since 1978. The first subline (Y) has been selected for high yearling weight without restriction on birth weight. Bulls for the second subline (YB) have been selected first for below average birth weight. Then, having culled those with above average birth weight, the remaining bulls are selected based on high yearling weight. At the conclusion of this experiment (1994), more than 3 generations of selection will have occurred. Genetic differences in birth weight and yearling weight large enough to be important should be detectable if they exist.

Data collection and recording are routine and consistent with Beef Improvement Federation recommendations for performance recording in beef cattle. Calves are weighed within 24 hours of birth, at weaning, after a two to four week adjustment to weaning, and finally after a 168-day postweaning gain test.

For this report, data are summarized to illustrate year-to-year differences in performance between the Y and YB sublines. Subsequent analyses will determine how these differences relate to expected progeny differences (EPD's).

Results

Selection applied. From 1978 to 1990, annual differences between selected bulls and all bulls of the subline (selection differential) for yearling weight in YB were 91% of those in Y. Thus, it is to be anticipated that average yearling weight in YB would only slowly diverge from Y. The sacrifice in yearling weight selection differential of 9% necessitated by concurrent selection for low birth weight is less than theoretically anticipated.

Throughout the course of this experiment, bulls chosen to be sires in YB were on average 14.1 pounds lighter at birth than bulls chosen to be sires in Y. However, bulls chosen to be sires in Y were on average 29.5 pounds heavier at one year of age than bulls chosen to be sires in YB.

Given the actual performance records, if bulls had been selected in each subline by the appropriate selection criteria without regard for any other factors, these differences would have been 19.2 pounds for birth weight and 48.6 pounds for yearling weight, respectively.

Response to selection. Bulls used to produce the first calf crop were selected initially to establish divergence of the sublines. During the first 3 years of this study, calves sired by YB bulls averaged 3.3 pounds lighter at birth than calves sired by Y bulls. For calves born in the most recent 3 years (1990 - 1992) this difference in birth weight had increased to 6 pounds. The figure below (Figure 1) details the trends in birth weight throughout this study.

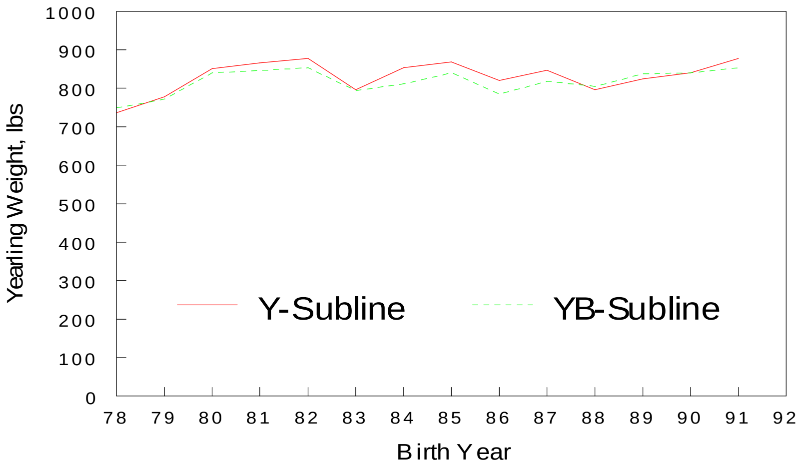

Figure 1. Trends in birth weight of Line 1 Hereford calves born 1978 to 1992.

During the first 3 years of this study, calves sired by YB bulls averaged 1.8 pounds lighter at one year of age than calves sired by Y bulls. For calves born in the most recent 3 years (1989 - 1991) this difference in yearling weight had increased to 3.5 pounds. Figure 2 details the trend in yearling weight throughout this study.

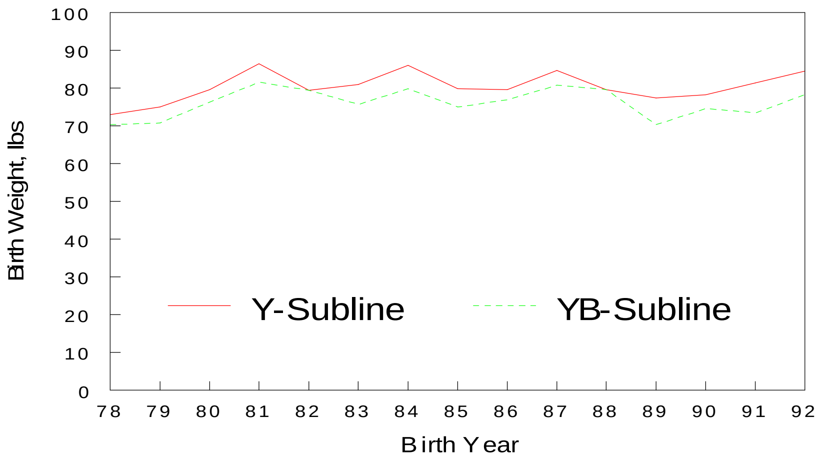

Figure 2. Trends in yearling weight of Line 1 Hereford calves born 1978 to 1991.

Conclusions

The results of this study illustrate the efficacy of a selection strategy that places considerable negative selection pressure in reducing the increase in birth weight that accompanies selection for growth. These results may suggest that selection strategies can be devised to further increase genetic potential for growth to 1 year of age without necessarily increasing birth weight. This result is important because cattle selected in this manner may reach market weight at a younger age while not increasing the incidence of dystocia or its after effects.

The Composite Breeding Program at Fort Keogh

S. Newman

Introduction

A large number of biological traits are important for economically and biologically efficient rangeland-based beef production. These include the ability to withstand environmental stress, a high level of fertility, low energy requirements (foraging ability), low incidence of calving difficulty, moderate calf birth weight, moderate milking ability, rapid growth rate, medium mature size, good temperament, and sound feet and legs. Unfortunately, these traits are not all found in one particular breed. Because differences between breeds are highly heritable, crossbreeding represents an opportunity to combine breeds to enhance productivity.

By developing structured crossbreeding programs that exploit heterosis (hybrid vigor) and heritable differences among breeds, breeders can produce a unique crossbred genotype to optimally fit each environment. Many types of crossing systems exist, and each has its advantages based upon amount of heterosis retained and certain management constraints, e.g., number of breeding herds to maintain system or source of female replacements. A primary limiting factor to the use of structured programs is the relatively small herd size of the average U.S. farm. It has been estimated that 53% of the U.S. beef breeding herd and 93% of the farms and ranches that have beef cattle are represented by units of fewer than 100 cows (National Agriculture Statistics, 1990).

An alternative to regular crossing systems is to perform one or a few crosses between two or more breeds to produce a single population called a synthetic or composite. Based upon conclusions from experimental results at the U.S. Meat Animal Research Center, Clay Center, Nebraska, composites offer the opportunity to: 1) use high levels of hybrid vigor on a continuing basis; 2) achieve and maintain optimum breed composition needed to match performance characteristics of the composite breeds to each of a wide range of production situations and to different market requirements; and 3) achieve and maintain uniform performance levels from one generation to genetic distance between them. Once the breeds have been combined and crossbred animals mated *inter se* (crossbred to crossbred), increased heritabilities are expected for all traits relative to straightbreds. Exploiting the increases in heritability and their relationship to increasing productivity of beef production in the Northern Great Plains forms the basis for the present study.

Experimental Design

The initial matings of the CGC project utilized Red Angus females mated to Charolais or Tarentaise sires (Fig. 1). Crossbred matings began in 1981.

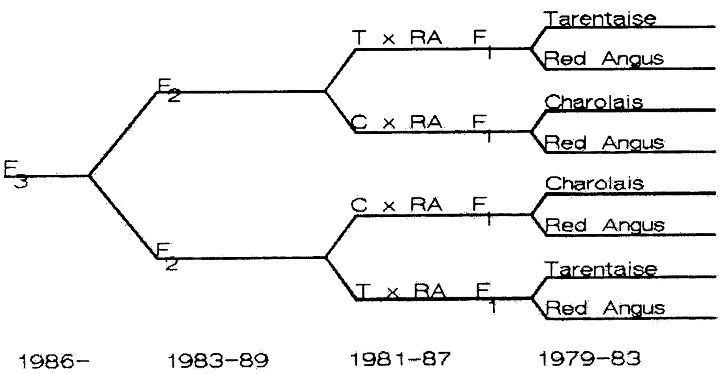

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Figure 1. Mating design of CGC development.

Sire selection

The experiment was designed to mate Charolais (C) sires and Tarentaise (T) sires to Red Angus females each year for 5 yr beginning in 1979. Semen was purchased from major A.I. suppliers or individual producers and only semen from progeny tested sires was used. Sires were repeated in later years. The criteria for selection of C sires were that: 1) they were polled and produced polled offspring; 2) their sires were not a recent importation from Europe; 3) they were moderate in mature size within the breed and calving records indicated they were near average or below average in calving difficulty; 4) they were average or below average in birth weight; and 5) they were moderate in pre- and postweaning gain ratio. Bulls advertised for use on only mature cows were not considered for the study. The criteria for selection of the T sires were that they were representative of the breed in mature size and most other traits. Sires with Expected Progeny Differences (EPD's) that were average or below in calving difficulty and birth weight and were average or above in pre- and postweaning gain ratio were selected. Only one sire from a grandsire or a granddam of each breed was used. A total of 14 C and 12 T foundation sires were used.

Female Selection and Management

In November and December 1978, 300 Red Angus females born in 1977 and 1978 were purchased from 12 different sources. Heifers came from herds where performance testing had been used for a number of years. Fifty of the heifers were about 18 mo of age and came from breeders that ordinarily mated heifers first at 2 yr of age, and 250 were weanling calves. They were fed to gain approximately 1.25 lbs daily during the winter months. On June 1, 1979, Red Angus yearling heifers averaged 645 lbs in weight and 2 yr old's averaged 772 lbs. In October, Red Angus 18-mo-old heifers averaged 816 lbs while the 2 yr old's averaged 926 lbs.

Before the breeding season in 1979, heifers were mated to 1 of 6 T sires or 1 of 6 C sires at random within age. They were all kept together on irrigated pasture and bred by artificial insemination (A.I.). Forage species were a mixture of grasses and legumes. The cows were rerandomized each year and were bred at the same unit for all 5 yr. A 45 d breeding season began on June 15 of each year. Cows remained on irrigated pasture until mid-October when calves were weaned. Cows were then placed on native range until grass became sparse or until vegetation was covered by snow. They were then moved into small pastures and fed approximately 20 lbs alfalfa hay/head daily.

In early March, heifers or cows were moved to calving pastures and continued to be fed approximately 20 lb alfalfa hay. The 2- and 3-yr-old's were placed in a pasture and observed during the daylight hours and at night when possible. The 4-yr-old's and older cows were placed on a range pasture and observed for 16 h/d.

Heifers were pregnancy tested in the fall of 1979 and all nonpregnant heifers removed from the study. In the spring of 1980, because of severe drought, it was necessary to reduce the number of breeding animals to 180 head. All cows that lost calves at birth, had a cesarean birth, and a few cow and calf pairs were removed. In the autumn of 1980 and thereafter, nonpregnant cows and physically unsound cows were removed from the project. Male calves were kept intact and no creep feed was offered to calves. Calves were moved into the feedlot for a 140-day postweaning growth test. Bulls were fed to gain about 3 lbs/day, while heifers were fed to gain about 1.75 lbs/d.

Data Collection and Analysis

Weights were recorded at birth and at weaning, when the calves averaged 180 days of age. After a two week adjustment period (postweaning), male calves were weighed on test for 140 days; weights were recorded every 28 days on both male and female calves. Pre- and postweaning average daily gains were calculated from these weights. Carcass information was collected only on surplus bull calves after the postweaning growth test and sire selection was completed. Carcass characters measured included carcass weight, fat depth, rib eye area, kidney, pelvic, heart fat, carcass grade, and marbling score. Retail product weight was predicted using information on fat depth, rib eye area, kidney, pelvic, heart fat, carcass weight, and marbling score. Pregnancy, calving and weaning rates were estimated as a proportion of cows exposed. For the initial phase, gestation lengths could be estimated because A.I. was practiced. All data was adjusted to common ages, sex of calf, sire breed, and age of dam when necessary.

Results

Growth, carcass, and reproduction data from phase I (C vs T sires) are presented by breed of sire in Tables 1, 2, and 3, respectively.

Table 1. Breed of sire means for growth characters.

	Weight (lbs)			Average Daily Gain (lbs/day)	
Sire breed	Birth	Weaning	Yearling	Preweaning	Postweaning
Charolais	83	475	848	2.2	2.0
Tarentaise	75	465	831	2.1	2.0

Table 2. Breed of sire for carcass characters.

Sire breed	Carcass Weight (lbs)	Fat Depth (in)	Rib Eye Area (in^2)	Kidney, Pelvic Heart Fat (lbs)	Marbling Score	Carcass Grade	Retail Product (lbs)
Charolais	627	.19	31.1	10.0	slight	select	471
Tarentaise	601	.19	12.7	11.1	slight	select	450

Table 3. Breed of sire means for reproduction characters.

Sire breed	Gestation length (days)	Pregnancy rate (%)	Calving rate (%)	Weaning rate (%)	Calving difficulty (%)
Charolais	283	87	81	75	21
Tarentaise	285	85	78	76	16

Charolais-sired calves were heavier at birth, weaning, and yearling than Tarentaise-sired calves. There was little or no difference in pre- or postweaning average daily gains.

Charolais-sired calves also had heavier carcass weights, which translated into greater retail product. Fat thickness was similar in both groups (.19"). Charolais-sired calves had slightly larger rib eye area and smaller amounts of kidney, pelvic, and heart fat than Tarentaise-sired calves. Average carcass grades were similar for both groups (select grade). Charolais-sired calves were leaner (slight -) than Tarentaise-sired calves (slight).

Charolais-sired calves had a shorter gestation than Tarentaise-sired calves. This was an unexpected result, considering the positive relationship between birth weight and gestation length.

Pregnancy and calving rates were greater for Red Angus cows mated to C sires, while weaning rates were greater for Red Angus cows mated to T sires. It is important to note that all 3 measures of reproductive performance are based on proportion of cows exposed. We believe that cows exposed is a much better indicator of herd productivity because it accounts for greater variability in life cycle production. If calving rate is put on a cow's pregnant basis, then average calving rate would be 90%. The same value (90%) is calculated if weaning rate is put on a cows calving basis.

Subsequent Performance

Analyses of all data collected to 1990 are presented in Table 4. The data have been adjusted for generation, age of dam, and sex of calf. Clearly, the stabilized composite seems to experience greater productivity than the initial F_1 crosses, no doubt due to the maternal heterosis of crossbred females. We have no method to estimate the heterosis effect from the crosses because purebred contemporaries were not included in the initial study. If we define heterosis as the difference in performance between crossbred and purebred performance, then the purebred information would be important.

Table 4. Summary of Composite Gene Combination (CGC) Project, 1980 to 1990.

Trait	Average performance	Number of observations
Pregnancy rate[a]	90.9%	3055
Calving rate[a]	87.4%	3054
Weaning rate[b]	95.7%	2614
Calving difficulty[c]	14.8%	2669
Gestation length[d]	284.0 days	701
Birth weight	81.0 lbs	2614
Weaning weight	454.0 lbs	2497
Final weight	981.0 lbs	1212
	704.0 lbs	1205
Preweaning ADG	2.1 lbs/day	2497
Postweaning ADG[e]	3.0 lbs/day	1212
	1.4 lbs/day	1205
Carcass weight[f]	646.0 lbs	803
Fat depth	0.2 in	803
Rib eye area	13.4 in^2	803
Marbling score	slight	803

[a] Cows exposed.
[b] Cows calving.
[c] Includes first calf heifers. Older age groups show markedly lower percentages (on the order of about 3%).
[d] First phase only (Red Angus females mated to Charolais or Tarentaise sires AI).
[e] Male and female progeny evaluated separately because they were fed differently postweaning.
[f] All slaughter animals were bulls.

Genetic Trends in Performance

The major breed associations require access to large computing facilities to complete genetic evaluations of registered animals and the estimation of breeding values. A breeding value is the genetic value of an animal as a parent. A breeding value is twice the Expected Progeny Difference, or EPD, since the parent only transmits a sample half of its genes to each progeny. The CGC population does not enjoy the access to performance information as the major breed associations do, but increases in availability of software to complete genetic evaluations "in-house" has provided us with the capability of estimating breeding values and genetic trends using all relationships and performance data. Figure 2 shows trends in breeding value for birth weight, weaning weight, and total maternal value. The total maternal value is calculated for traits that are influenced both by the direct effects of the calves' genes as well as the maternal effect (mostly milk production) of its dam. It is calculated as one-half the breeding value for weaning weight plus the maternal breeding value for weaning weight. Since 1980, there has been little overall change in birth weight, changing at about 0.1 lb per year. Weaning weight has been increasing at the rate of 0.8 lbs per year and total maternal about 0.6 lbs per year.

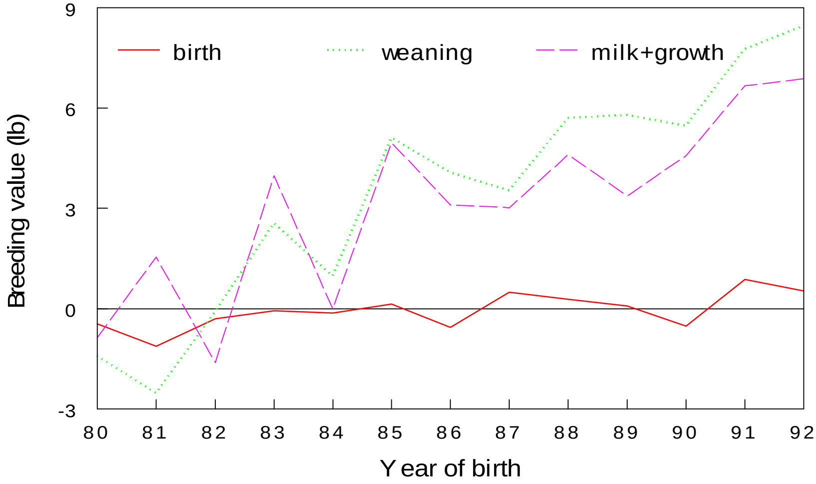

Figure 2. Genetic trend in birth weight, weaning weight, and total maternal value.

Figure 3 portrays genetic trend in yearling weight, which is changing at the rate of about 3.0 lbs per year. In general, there seems to be sufficient additive genetic variation in most traits of economic importance in the CGC population.

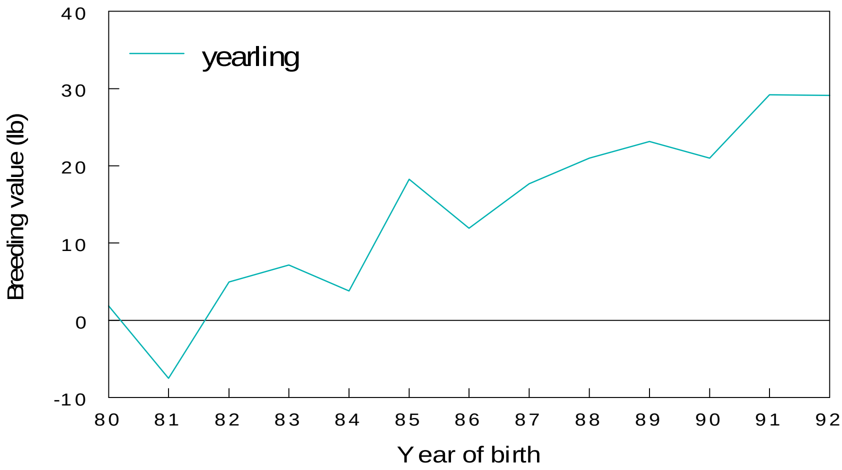

Figure 3. Genetic trend in yearling weight.

Future Plans

In 1988, two selection lines (plus control) were begun in the CGC population. The first line selects bulls on the index I = yearling weight -3.2(birth weight). This index discounts heavier birth weight bulls while (theoretically) decreasing yearling weight by about 10%. The second line utilizes the ratio of calf weaning weight to cow weight for bull selection. This ratio has been used by many producers as an indicator of maternal productivity, assuming that the dam's weight is related to annual feed requirements. Research from South Dakota State University has shown that using cow weight increases accuracy of predicting efficiency by only 3% over using weaning weight alone. The present study represents the first attempt to genetically change a population for this ratio. This phase will be terminated with the 1994 calf crop.

Recent Publications

Newman, S., M.D. MacNeil, W.L. Reynolds, B.W. Knapp, and J.J. Urick. 1993. Fixed effects in the formation of a composite line of beef cattle. I. Experimental design and reproductive performance. J. Anim. Sci. 71:2026-2032.

Newman, S., M.D. MacNeil, W.L. Reynolds, B.W. Knapp, and J.J. Urick. 1993. Fixed effects in the formation of a composite line of beef cattle. II. Pre- and postweaning growth and carcass composition. J. Anim. Sci. 71:2033-2039.

Beef Cattle Breed Use in the Northern Great Plains

M.D. MacNeil, W.L. Reynolds, and J.J. Urick

Introduction

Breed resources present opportunities to match genetic potential for production with environmental resources and product characteristics with consumer demands. Applicability of results from comprehensive breed evaluations conducted under intensive pasture conditions to extensive rangeland based beef production remains unknown. Research was conducted using the Angus, Pinzgauer, Red Poll, and Simmental breeds representing broad genetic variability in genetic potentials for growth and milk production to address these issues.

Methods

From 1974 to 1977 Angus, Pinzgauer, Red Poll, and Simmental sires were bred to Hereford cows to produce first-cross calves that were evaluated for calving characteristics and growth to weaning. Male calves were subsequently fed individually until slaughter when their carcasses were evaluated. Female calves were developed as replacements and evaluated for maternal performance through 6 years of age (1977 to 1984). Philosophically, the cattle were managed as typical of extensive ranching operations in the surrounding area. Breeding of the crossbred females was to Shorthorn bulls for their first calf and to Charolais bulls thereafter.

Semen from the same Angus, Pinzgauer, Red Poll, and Simmental sires was also used in breed evaluation research conducted at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska. As at Miles City, male progeny were slaughtered and their carcasses evaluated, and female progeny were evaluated for maternal performance. At Clay Center, cattle were managed throughout the year to meet the nutritional requirements of those cattle with highest levels of genetic potential for production.

Results

Breed of sire of the calf caused gestation lengths to differ. Angus sired calves had shorter gestation periods than Pinzgauer, Red Poll, or Simmental sired calves. Cows bred to Pinzgauer and Simmental bulls more frequently required assistance than cows bred to Angus or Red Poll bulls, particularly as 2-year-old's. Increases in growth from birth to weaning as a result of mating to Pinzgauer and Simmental sires were not realized. In fact, differences in weaning weight per cow exposed were quite small among all breeds studied (Fig. 1). This result is most likely due to the maternal ability of the Hereford cows to which these bulls were bred not providing a sufficient maternal environment to allow expression of maximum genetic potential for growth.

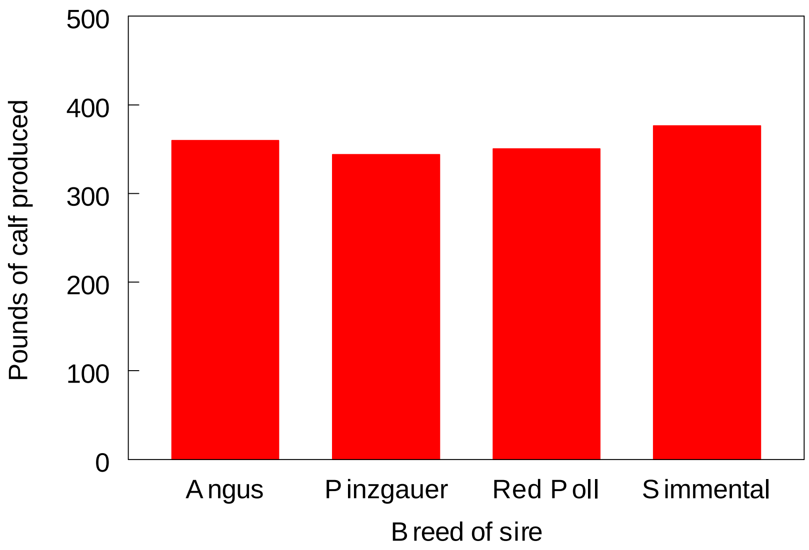

Figure 1. Weaning weight produced per cow exposed by crossbred calves from Hereford dams.

Differences in postweaning growth, feed efficiency, and carcass composition of the first-cross steer calves were large enough to be of economic importance to feedlot operators. Simmental-sired steers grew most rapidly to age or weight constant endpoints and produced the greatest yield of acceptable retail product among the breeds studied. Under the conditions of this study and the current market environment, only the Angus-sired steers tended to be too fat at age or weight constant endpoints and alternatively too light in weight at a desirable degree of finish.

Despite development of the heifers consistent with commonly accepted recommendations, all breeds exhibited one or more years of aberrantly low pregnancy rate with the higher milking Red Poll and Simmental heifers on average having lower pregnancy rates that their lower milking Angus and Pinzgauer counterparts. While Pinzgauer- and Simmental-sired heifers exhibited their greater genetic potential for growth after weaning, they also experienced calving difficulty more frequently than Angus- and Red Poll-sired heifers. However, genetic predisposition to neonatal mortality did not follow directly from differences in dystocia. Rather, no significant differences were detected in calf losses from birth to weaning. Reduced pregnancy rate, calving difficulty, and calf death losses represent risks that cattle producers can manage through appropriate selection among breeds and possibly other forms of intervention.

It seems probable that Simmental-sired females would have the greatest total maintenance requirement and requirement per unit of body weight. They would also be expected to have the greatest requirements for growth and lactation, given that they performed these functions at the highest level among the breeds studied. Generation of estrus cycles and initiation of pregnancy have been postulated to have lower energetic priority for the beef cow than basal metabolism, growth, and lactation. Thus, we theorize that Simmental-sired females were not able to meet threshold requirements for energy for the combination of Northern Great Plains rangeland and supplemental feed provided at Miles City. This energy deficit was manifested in reduced pregnancy rates.

Thus, we conclude that selection among Angus, Pinzgauer, Red Poll and Simmental breeds for use as maternal strains when crossed on Hereford cows was not arbitrary in the Northern Great Plains environment. Judging from weaning weight per cow exposed (Fig. 2) and longevity (Fig. 3), Simmental and to a lesser extent Pinzgauer-sired females may exemplify the consequences of overmatching available range resources with genetic potentials for growth and milk production. While maternal genotype effects on neonatal calf survival were not significant, they may have been judging from the frequency of dystocia, had labor resources to closely monitor calving not been available.

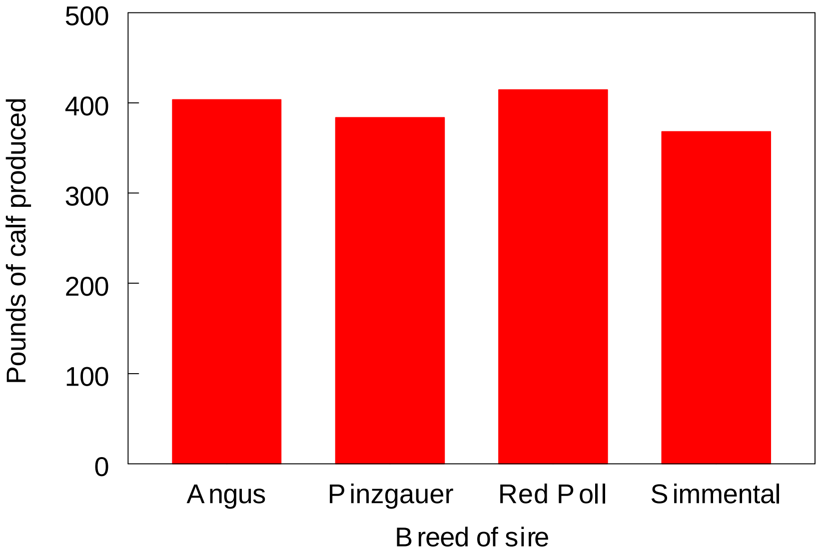

Figure 2. Weaning weight produced per cow exposed by crossbred females from Hereford dams.

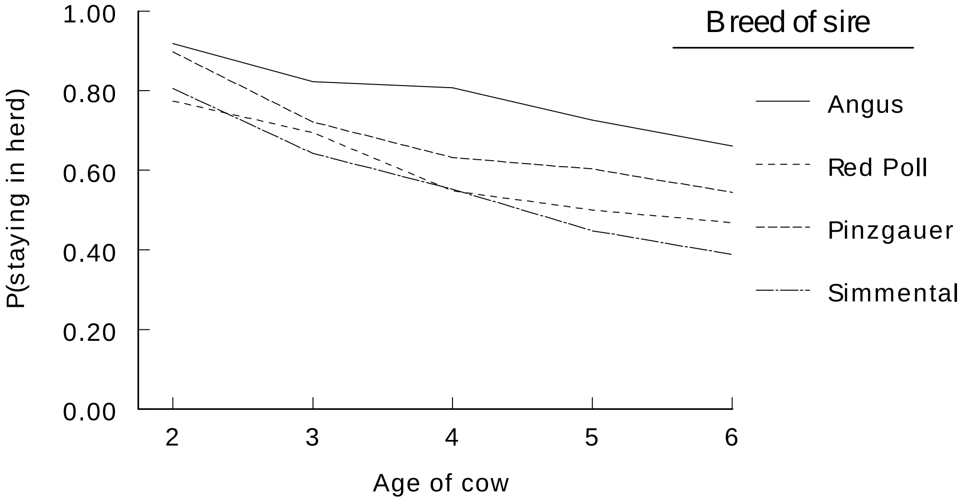

Figure 3. Probability (P) of crossbred cows from Hereford dams remaining in the herd.

For many traits indicative of individual and maternal performance, significant differences exist between genetically similar type of cattle raised at Miles City, Montana, and Clay Center, Nebraska. However, differences between breeds were remarkably similar across both locations, except for pregnancy rate of the crossbred females. At Clay Center, all crossbred females had pregnancy rates in the range 87% to 93%; whereas, at Miles City, Angus, Pinzgauer- and Red Poll-sired females had pregnancy rates from 92% to 95%, and Simmental-sired females only achieved an 81% pregnancy rate.

Conclusions

For most production traits large, comprehensive breed evaluations conducted at relatively few locations adequately represent genetic differences among breeds. However, location effects may be important in altering absolute levels of performance. Some caution is advised in assuring adequate feed resources to meet nutritional requirements of the cow. For those producers providing low levels of feed input, easy fleshing maternal breeds with less than maximum genetic potential for growth and milk production are recommended. These producers can achieve desired carcass endpoints through wise use of terminal sires on older cows. In the research at Miles City, Angus-Hereford cross females excelled in lifetime productivity and produced calves with only slightly lower cutability and more finish than other crosses when mated to a terminal sire breed.

Recent Publications

MacNeil, M.D., L.V. Cundiff, J.J. Urick, R.M. Koch, W.L. Reynolds, K.E. Gregory, S. Newman, B.W. Knapp, and D.B. Laster. 1993. Evidence for interactions among year, sire, breed and location affecting performance of beef cattle in Montana and Nebraska. J. Anim. Sci. (submitted).

MacNeil, M.D., W.L. Reynolds, and J.J. Urick. 1993. Cow weight and condition score, pregnancy rate and maternal productivity of crossbred beef females. J. Anim. Sci. (submitted).

Reynolds, W.L., J.J. Urick, B.W. Knapp, and M.D. MacNeil. 1991. Maternal breed of sire effects on postweaning performance of first-cross heifers and production characteristics of 2-year-old heifers. J. Anim. Sci. 69:4368-4376.

Urick, J.J., M.D. MacNeil, and W.L. Reynolds. 1991. Biological type effects on postweaning growth, feed efficiency and carcass characteristics of steers. J. Anim. Sci. 69:490-497.

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Molecular Genetic Approaches to Beef Cattle Improvement

S. Newman, D. Pomp, N. Muggli-Cockett,
D. Moody, and M.D. MacNeil

Introduction

Permanent genetic improvement of livestock takes place through selection programs, where animals of superior genetic merit for the trait(s) under improvement are used as parents to produce a generation of offspring whose average performance is better than the previous generation. Modern breeding programs utilize sophisticated selection procedures that estimate an animal's genetic potential through evaluation of its phenotypic performance as well as the performance of its relatives (ancestors, sibs, progeny, etc.).

Annual genetic gain for any trait of economic importance is a function of the heritability of the trait, the selection pressure applied to the population, the accuracy of selecting the best animals, and the time required to turn over generations and incorporate the improved germplasm. Seedstock producers have control over two of these, namely accuracy of selection and generation interval. Of course, the efficiency in which selection is made can be less efficient if environmental influences are not accounted for. Furthermore, since most traits of economic importance are quantitative, i.e., are controlled by many pairs of genes, sampling variation may preclude the transmission of the best genes from the selected parents to their offspring.

There have been remarkable developments made in the field of molecular biology that now afford the animal breeder, for the first time, the opportunity to begin to attempt to identify animals of superior genetic merit by direct analysis of DNA. This technology will allow the breeder to determine which types of genes cattle actually possess at loci which influence growth, reproduction, and carcass quality. The development of techniques for the detection of molecular-genetic variation are advantageous to genetic improvement because: 1) selection can occur at younger ages; 2) there is increased capability for indirect selection of sex-limited traits (e.g., milk production); and 3) there is an increased accuracy of selection.

This technology is known as *marker assisted selection* (MAS). Markers are simply identifiable regions of DNA that are linked to genes which control economic traits. This technology is still in its infancy, but an increasing number of markers are being identified in different species of livestock that are associated with traits of economic importance. This report is a description of a cooperative project between Fort Keogh, Oklahoma State University, and Utah State University to characterize the inbred Line 1 population for a number of genetic markers.

The Language of DNA

Deoxyribonucleic acid (DNA) is a polymer of sugars, phosphoric acid, and four nitrogen-containing bases: guanine, cytosine, adenine, and thymine (Fig. 1). DNA has a characteristic double helix shape. When the bases link to a sugar, the structure is called a nucleoside. The structure becomes a nucleotide when a phosphate bond is added. Chains of nucleotides bond together to form DNA. A sequence of 3 nucleotides codes for a specific amino acid (e.g., methionine, cysteine, lysine, etc.). Amino acids coded by the base sequence of DNA are joined together to form proteins. There could be from 100 to 1000 amino acids in a protein. Based upon this structure, a gene contains the information required to synthesize a protein. Finally, genes are located on chromosomes, which are simply tightly coiled DNA. Cattle possess 30 pairs of chromosomes, one inherited from each parent.

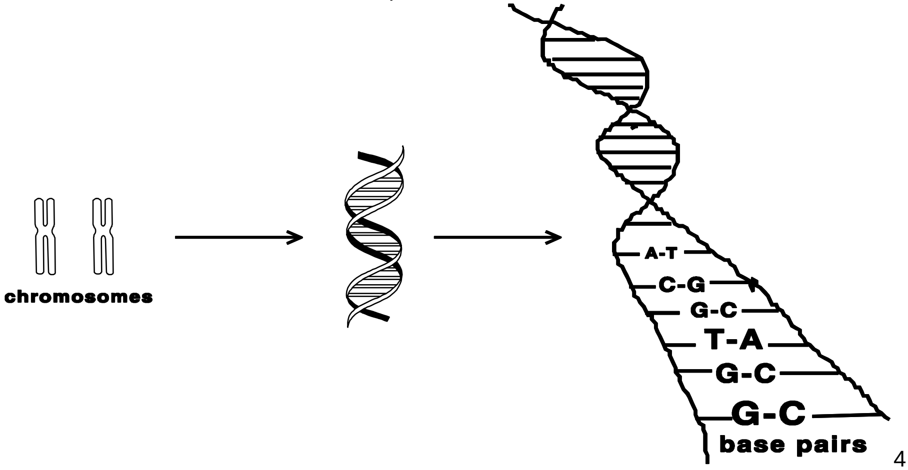

Figure 1. Chromosomes are structures of tightly coiled DNA. DNA has a characteristic double helix shape, and is composed of sugars, phosphoric acid, and four nitrogen-containing bases.

Experimental Procedures

A blood sample is collected from a calf at branding. The blood is brought into the lab, where a buffer solution is added that destroys red blood cells but keeps white blood cells intact (red blood cells have no nuclei, where DNA resides). The white blood cells are washed repeatedly to remove the buffer and re-suspended. DNA can be extracted at anytime after this point, using a salt extraction method. The DNA is measured for concentration and purity and stored. The cooperators genotype the animals for markers of interest. By identifying the genotype of each individual in the population, we can correlate the genotype with the phenotypic performance of the individual. If a significant association is found, then there is evidence that a major gene influencing the trait of importance is close by. Further testing is instituted to confirm this result. DNA can be extracted from semen, milk, tissue, and hair.

The Polymerase Chain Reaction, or PCR, is used to identify molecular differences in DNA. PCR uses a series of enzymatic reactions to amplify a specific region, or gene, from the DNA of an animal. After a gene has been amplified, it can be studied using gel electrophoresis. One technique uses restriction enzymes which cut the genes at different locations. This results in different sizes of DNA fragments depending on which forms of the genes are present in the animal.

Another PCR-based technique looks at differences in microsatellite regions within genes. A microsatellite is a region of tandem repeats of a short DNA base sequence. Different forms of a gene often have different numbers of repeating sequences within microsatellite regions. PCR will amplify the microsatellite region of the gene resulting in DNA fragments of different lengths. These DNA fragments can then be separated using gel electrophoresis to determine which form of the gene is present in the animal.

Marker Frequency Variation

Efforts are being made to cover as much of the cattle genome as possible with markers associated with a wide array of physiological processes. Collaboration with Utah State University has concentrated on markers associated with disease resistance. Work with Oklahoma State University has focused on markers related to growth and reproductive processes. Information to date on genetic characterization of inbred Line 1 Hereford cattle at Fort Keogh is presented. Comparison to other populations is made when data are available.

Genes that function to control the immune system are located in very close proximity on 1 chromosome. This gene complex is known as the *major histocompatibility complex* (MHC). The specific alleles of the MHC locus are considered to be responsible for the differences in resistance or susceptibility to certain diseases. Because the location of these genes is relatively well understood, it seemed logical to test the hypothesis that these genes may act as markers related to traits of economic importance.

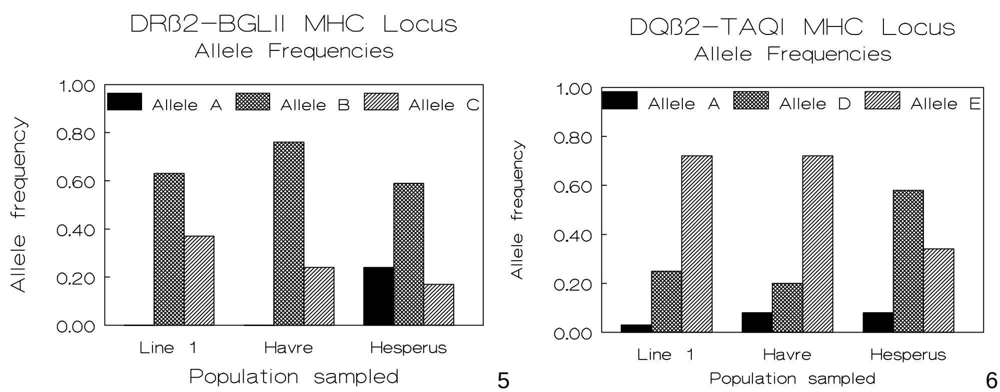

Figure 2. Allele frequencies of disease resistance markers in three populations of Hereford cattle.

Figure 2 presents data from two of four MHC loci found in Line 1 (107 individuals) plus 2 other populations: 1) the Hereford herd from the Northern Agricultural Research Center, Havre, which is composed of cattle related to Line 1 (mostly Line 4 breeding; 44 individuals), and 2) animals sampled from the long term breeding project at the San Juan Basin Research Center, Hesperus, Colorado (44 individuals). The Line 1 and Havre samples are similar to one another as a major portion of the sample were Line 1 influenced animals. Alternatively, we note that for DRß2-BGLII, a third allele was detected in the Hesperus population that was not found in the other two. For DQß2-TAQI, the frequency of allele D is much greater and of allele E much smaller than the other two populations. This points to the important impact that founding individuals have on a closed population.

Markers associated with growth and reproduction are presented in Figure 3. Four different populations are compared: 1) Line 1 Herefords from Fort Keogh. This is a closed population since 1934, and has been under selection for postweaning growth since that time; 2) Lents Anxiety 4th Herefords, Indiahoma, Oklahoma. The Lents herd has been a closed population since 1881, and all cattle can be traced back to the sire Anxiety 4th. It provides an excellent basis for comparison with Line 1 because there has been no Line 1 influence and have not experienced intentional selection for growth; 3) the highest Hereford sires for yearling weight EPD and accuracies greater than .75 in the U.S. Sire Summary. These animals exceed the average of the breed for yearling weight, and will be an excellent indicator of total growth potential; 4) the lowest Hereford sires for yearling weight EPD and accuracies greater than .75.

Five markers have been analyzed in sires from the above 4 populations (Fig. 3). The graphs represent 12 Line 1 sires, 8 Lents sires, 13 high EPD sires, and 14 low EPD sires. The markers analyzed include kappa casein and beta lactoglobulin (milk proteins known to affect quality and yield of processed milk products), insulin-like growth factor (IGF; mediates many growth promoting effects of growth hormone), prolactin (a pituitary hormone that stimulates milk production in females), and corticotropin releasing hormone (CRH; an important factor in mediating stress-induced inhibitory effects on reproductive functions). For these populations, 2 alleles, or alternative forms of the genes were found at each marker locus.

There is little difference in allelic frequencies among the populations for kappa-casein. It would seem that selection for postweaning growth is not affected by this locus. Both beta-lactoglobulin and IGF allele frequencies show the effect that closing of a population to outside influence can have on gene frequencies. We surmise that the founding individuals in the Line 1 and Lents herds had high frequency of the A allele for beta-lactoglobulin and IGF. Thus, at least for the Lents herd, the A allele was fixed early in the breeding program. The B allele of beta-lactoglobulin was of much higher frequency in the high- and low-EPD herds than in Line 1. This is an interesting finding considering the influence that Line 1 has had on the general Hereford population, where over 65% of cattle have some Line 1 influence in their ancestry. All samples exhibited high frequencies for the A allele at the prolactin locus, where it is fixed in Line 1 and the Lents herd. It is interesting to note that the frequencies of the CRH alleles are reversed in the Line 1 and Lents sires. Except for beta-lactoglobulin, allele frequencies of the high- and low-EPD sires compared favorably with Line 1.

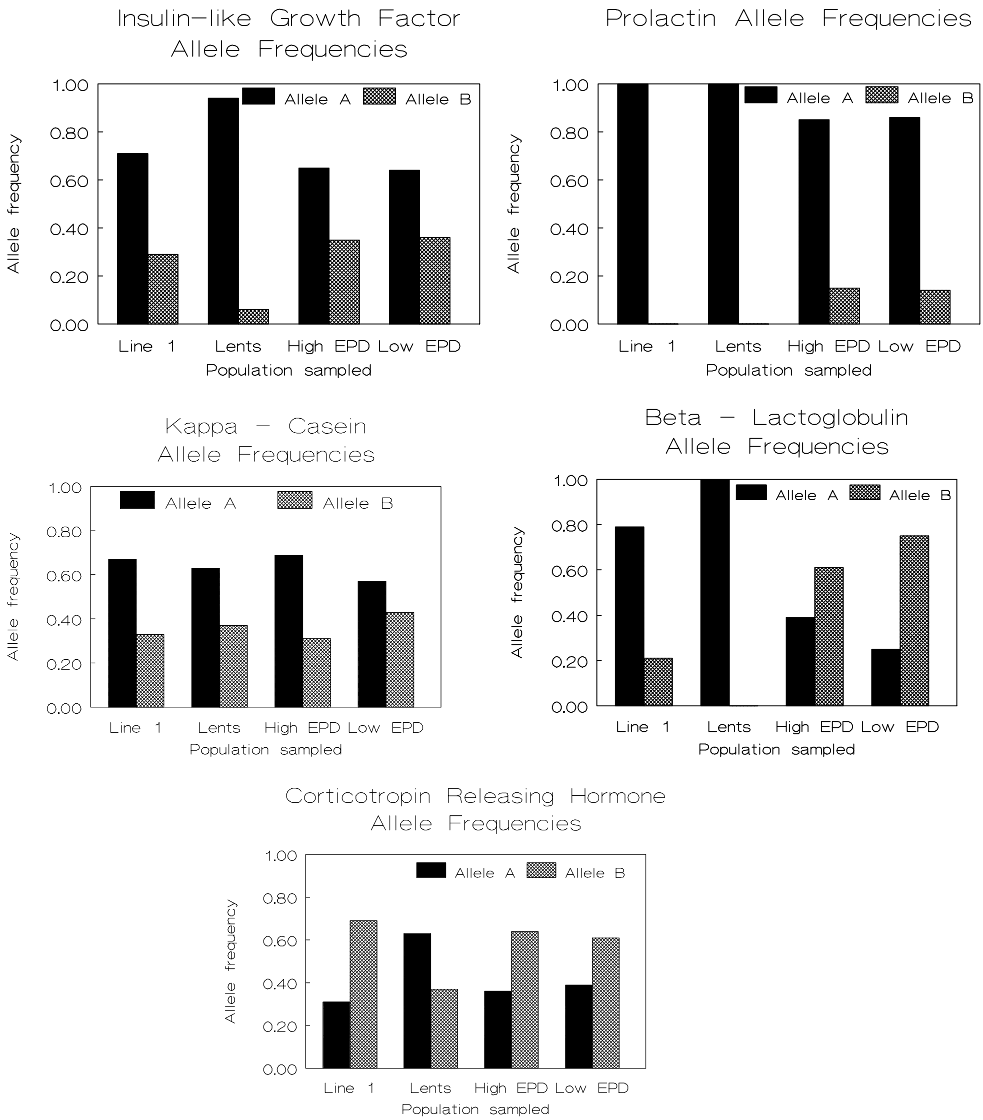

Figure 3. Allele frequencies of genetic markers associated with growth, milk production, and reproduction.

Conclusions

Progeny from the Line 1 and Lents herds are being sampled over a period of years to look at allele and genotype frequencies in the progeny. Work has just started in relating performance information with genotype at these marker loci. If markers are found that identify the presence or absence of the actual genes in prospective breeding animals that influence economically important traits, then breeders could submit blood or tissue samples from their animals at an early age for an evaluation of their actual genotype. Thus, the breeder could know well in advance of the selection decision which animals to keep and which to cull.

The Potential Importance of Cow Families as they Affect Growth from Birth to One Year of Age

M.D. MacNeil and M.W. Tess

Introduction

Cow families are thought by some breeders to be more important than standard methods of genetic evaluation would indicate. These breeders expect descendants of certain cows to perform at a level above that which would be predicted from their expected progeny differences (EPD's). Since virtually all the extra-nuclear material present at conception comes from the maternal line and some genetic material is known to be present outside the nucleus of cells, a biological mechanism for this phenomena exists. The importance of this genetic material that is present outside the cell nucleus, to birth weight, gain from birth to weaning, and gain from weaning to 1 year of age was investigated in this study.

Methods

Pedigrees of Line 1 Hereford cattle were traced for 5 generations preceding the establishment of the line in 1934. Using these pedigrees and those kept since the line was formed, the maternal lineage of all animals born in Line 1 from 1935 to 1989 was determined. Direct and maternal EPD's were computed for all animals and the amount of variation in birth weight, gain from birth to weaning, and gain from weaning to 1 year of age attributable to their maternal line were estimated concurrently.

Results

There were 26 cow families found present in pedigrees of Line 1 Hereford calves born from 1935 to 1989. These cow families accounted for less than one-tenth of 1% of the total variation in birth weight, gain from birth to weaning, and gain from weaning to 1 year of age. In comparison, estimates of direct and maternal heritability were, respectively: birth weight 37% and 13%, gain from birth to weaning 16% and 23%, and gain from weaning to one year of age 35% and 6%.

Conclusions

While extra-nuclear genetic material is known to have important influences on some biochemical processes, its affect, if any, on growth to one year of age is very small. Therefore, given the much larger and established effects on performance predicted by EPD's, breeders would be well advised to place their selection emphasis for growth on the EPD's rather than on maternal lineage.

Recent Publications

Tess, M.W., M.D. MacNeil, and K.C. Davis. 1991. Evaluation of cytoplasmic genetic effects in a closed line of Hereford cattle. J. Anim. Sci. 69, Suppl. 1:203.

Selecting Beef Cattle for Genetic Improvement in Profitability

S. Newman and M.D. MacNeil

Introduction

Genetic evaluation of beef cattle is accomplished through computer services processing of pedigree information and performance records. The outcome is a series of Expected Progeny Differences, or EPD's. Given a number of candidates for selection, all with EPD's for the relevant performance traits, objectively deciding which animal to use remains difficult. Genetic evaluation procedures, which produce EPD's, should be considered as a means to an end (and not the end). The desired end is an improved economy of producing consumable livestock products for benefit of all consumers. The weakest point of genetic evaluation, as often implemented, concerns the definition of a basis for selection (breeding objective) that provides economic direction for the process. The purpose of this paper is to report on work toward the goal of including economic evaluation in genetic improvement schemes.

Structured Breeding Programs

Any successful breeding program has an overall objective or goal which is consistently followed. The general structure of a breeding program involves: 1) defining the breeding objective; 2) choosing appropriate selection criteria; 3) organizing a performance recording scheme; 4) using the recorded information to make selection decisions; and 5) using the selected individuals. Failure to adequately define a proper breeding objective could result in genetic change that compromises profitability.

A breeding objective is a statement of the traits in the breeding program to improve, and the emphasis given to each one. In other words, a breeding objective is the outcome a breeder desires from his breeding program (not the means for achieving it, but the *end result* desired). For example, the breeder may wish to increase net reproduction (calves weaned per cow exposed) as the highest priority, increase carcass weight as a second priority, and maintain birth weight at current levels as a third priority.

Unlike many business decisions, genetic improvement in herd production is realized many years after the decisions are made. Thus, breeding objectives must be based on economic judgements of *future* marketing conditions. These decisions will also be dictated by the general structure of the beef cattle industry, such as that portrayed in Figure 1. A pyramid structure is used as a metaphor representing expansion and dissemination of genetic improvement from selection down through the tiers to production and on to consumption motivated by value-based marketing. Likewise, economic signals concerning product characteristics ideally flow from the consumption sector back to seedstock producers. Requirements of the seedstock producer's clients need to be considered when choosing breeding objectives, as the clients' herd will be moved in the direction chosen by the seedstock producer.

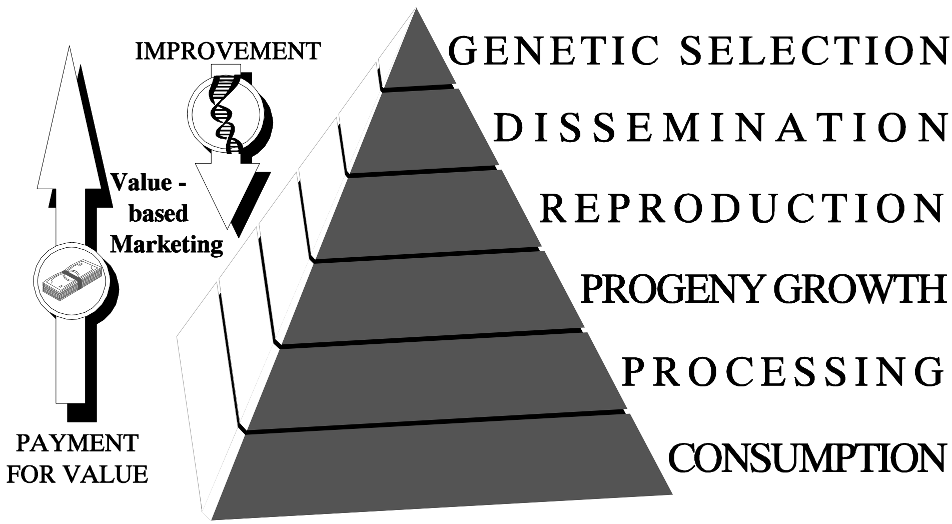

Figure 1. Structure of the U.S. beef cattle industry.

Traits to be included in the breeding objective must have three important features: 1) the trait must be heritable; 2) the trait must be definable; and 3) the trait must have economic value. Some traits are difficult or expensive to measure (e.g., food intake), but this is not justification to omit them from the breeding objective. Information may be obtained on these traits by measuring characters which are genetically correlated (linked) to them.

The breeding objective depends on the role of the breed 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. Biological characters of economic importance are usually associated with reproductive performance of the dam or growth and carcass of the progeny. In maternal lines, there would be greater emphasis on increasing reproductive performance. In terminal sire lines, greater emphasis would be put on growth and resulting carcass quality and quantity. General purpose lines may represent pure breeds, combinations of breeds called composites, and breeds used in rotational crossing systems.

There is a need to determine the relative contribution to profitability of traits in a breeding objective. For each trait, the net result in profit from a genetic change of one unit is termed its *economic value*. In defining economic value, it is necessary to consider both the extra returns and the additional expenses (or risks) associated with improvement of each trait.

Some traits in the breeding objective may be difficult or expensive to measure, like food intake. Thus, we often rely on indicator traits, called *selection criteria*, that are the characters used in the estimation of breeding values of the animals. In general, selection criteria should be heritable (have genetic variation), be relatively simple and inexpensive to measure on-farm, be measured relatively early in life, and be genetically correlated with traits in the breeding objective. The basic aim is to *maximize response in profit (end) by using the most appropriate set of selection criteria to achieve that end*.

Once the breeding objective is defined, economic values estimated, and selection criteria chosen, genetic information on these traits (heritabilities, genetic, and phenotypic correlations) is gathered. All of this information is used to derive a *selection index*, which forms the basis for choosing candidates for selection. Index selection is when all selection criteria are combined in 1 overall estimate of genetic merit. Animals are selected based upon their index value. The index takes the form

$$I = b_1X_1 + b_2X_2 + b_3X_3 + ... + b_nX_n$$

where the b's correspond to weighing factors, and the X's represent phenotypic measurements on selection candidates. If the b's are calculated appropriately, index selection is always the most efficient method of improving profitability. However, all measurements on the animal (and those from any relatives) need to be available at the same time.

How can this information be incorporated directly in the selection process? The expression above can be formulated in a different way to reflect the economics of the production system with the use of genetic evaluation as:

$$I = a_1EPD_1 + a_2EPD_2 + ... + a_nEPD_n$$

where the a's correspond to relative economic values for each EPD trait of interest. Thus, the index value (I) for each selection candidate corresponds to some overall economic ($) measure of genetic merit.

Examples

Tables 1-4 provide examples of traits found in breeding objectives and resulting sets of selection criteria for general purpose, maternal, and terminal sire lines of beef cattle. Economic traits are those included in the breeding objective, while performance traits are those selection criteria used to make decisions on selection candidates. Records from close relatives (e.g., sire, dam, sibs) were used in the estimation of index weights. Selection emphasis is included as a measure of relative weight put on performance traits in the selection index. A plus or minus sign signifies direction of response; a zero indicates no appreciable effect. In general, emphasis of selection was directed for reproduction in maternal lines, growth and carcass in terminal sire lines, and a balanced emphasis in general purpose lines.

Table 1. Example of breeding objectives and selection indices for terminal sire and maternal lines. Data from Beefbooster group breeding scheme. Distinctions between maternal and terminal sire lines a function of differing relative economic values. Food intake for cow-calf segment predicted from cow weight and maternal ability. Carcass quality defined by dressing percentage, meat yield, and percent in the Canadian A grade.

		Selection emphasis	
Economic traits	Performance traits	Maternal	Terminal
cow weight	birth weight	- - -	-
male fertility	calving day	0	0
female fertility	preweaning ADG	+	- -
calf survival	postweaning ADG	-	+ + +
weaning weight	scrotal circumference	+ + +	+ + +
background ADG	ultrasound fat depth	+ +	- - -
finishing ADG	cow weight	- -	+ +
feed conversion			
% A grade			
dressing %			
cutability %			

Table 2. Example of breeding objectives and selection indices for general purpose composite. Data from composite herd at Fort Keogh. Model of MacNeil et al., (1993) used to generate economic values. Carcass quality defined by meat yield alone. Target market is 18-mo slaughter animals weighing 1200 lbs.

Economic traits	Performance traits	Selection emphasis
weaning rate (calves/cow)	birth weight	-
weaning weight	calving day	-
finishing ADG	scrotal circumference	+
carcass yield	weaning weight	+ +
cow weight	yearling weight	+ +
feed conversion	ultrasound fat depth	+

Table 3. Example of breeding objectives and selection indices for terminal sire and maternal lines. Data from Landcorp Farming breeding scheme, New Zealand. Food intake incorporated directly into profit equation. No measure of carcass quality used because of lack of premiums for leaner carcasses. Target market is 18 to 20 mo. steers and heifers for export market.

Economic traits	Performance traits	Selection emphasis
weaning rate (calves/cow)	weaning rate	+
carcass weight	birth weight	+
food intake	weaning weight	+
	yearling weight	-
	scrotal circumference	+

Table 4. Examples of breeding objectives and selection indices for terminal sire and maternal lines. Data for domestic market calves, southern Australia. Target market is 9 mo. -old calves sold after weaning.

Economic traits	Performance traits	Selection emphasis
calving day	live weight at 9 mo.	+
carcass weight (9 mo)	ultrasound fat	-
fat depth	calving day	-
food intake		

Economic values pose other challenges. Breeding objectives require planning horizons that may span 20 years, but the available statistics may be of historical nature. The necessity of economic data recorded across several years to calculate relative economic values with reasonable precision suggests a need for long-term commitment to systematic recording of both economic and production information at the commercial cow-calf level. Furthermore, if selection indexes are eventually utilized in the beef cattle industry, the problem of who will develop breeding objectives (and economic values) will need to be addressed.

Economic values for reproduction in the studies cited in Table 1 were of much greater magnitude than those values associated with carcass composition or growth rate. However, performance measures (EPD's) for reproduction are lacking in genetic evaluation schemes. Thus, there is a need for further research into those indicators of reproduction that are most highly related to profit.

Additional efforts seem warranted to make the definition of breeding objectives and their use more complete and more accurate. Profit functions need to be extended to provide a full life-cycle perspective including longevity, re-breeding, viability, and reproduction. Where possible, performance recording schemes need to be expanded to include these traits in genetic evaluation. Where these traits cannot be routinely included, highly heritable, highly correlated indicator traits need to be defined.

Both research and implementation emphases for genetic improvement programs need to advance from making best use of whatever data is submitted to guiding design of integrated breeding programs that maximize the rate of economic improvement of livestock production. An economically sound breeding objective is key to interlocking beef breeding and production into a synergistic mutually beneficial relationship.

Recent Publications

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

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

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Genetic Relationship of Mature Size to Carcass Composition in Beef Cattle

M.D. MacNeil, N. Speer, and J.S. Brinks

Introduction

Consumers in the U.S. continue to demand leaner beef products. This signal has been delivered to beef producers through price incentives paid based on carcass characteristics and on apparent breed composition of live animals. As a result, producers are developing production strategies to produce a product capable of garnering these incentives. Further, seedstock breeders are putting additional emphasis on reducing fat when making selection decisions.

Consequences of selection for leaner carcasses on production efficiency in the cow-calf sector of production are largely unknown. The objective of this study was to evaluate genetic relationships between size of mature cows, and by inference their feed requirements, with carcass characteristics of steers slaughtered at desirable weights.

Methods

Data collected by Urick, Pahnish, and others from 1962 to 1977 in a crossbreeding study involving Angus, Charolais, and Hereford at Fort Keogh were used in this research. From 1962 to 1965, straightbred sires and dams were used to produce straightbred and all possible crosses of these three breeds. From 1965 to 1967, crossbred sires were bred to straightbred and crossbred dams to produce three-way cross calves. Then from 1967 to 1977, 2- and 3-breed rotational crossing systems and a composite were compared.

In the course of the study 690 cows, 402 bulls, and 473 steers were produced. Male cattle were slaughtered and carcass traits recorded at 1000 to 1050 pounds live weight. As part of his Ph.D research, Nevil Speer analyzed the data to estimate genetic correlations between cow weight at maturity and weight-constant carcass traits in the bulls and steers.

Results

Correlations of mature weight with days on feed and fat thickness were highly negative. Selection to reduce days on feed to a fixed weight endpoint or for reduced fat thickness in the slaughter progeny, will result in producing females that will develop into larger cows. Correlations between marbling score and mature size indicate that selection for carcasses with high levels of marbling will cause a reduction in cow size. The correlation between rib eye area and cow size was relatively small. These correlations of components of yield grade with cow size resulted in a small negative genetic association between cow size and yield grade at a fixed carcass weight.

Conclusion

It appears selection focused on producing carcasses with a greater proportion of lean also results in producing larger cows. Results from other research would suggest that these cows would also be later maturing with greater per animal feed requirements. These tradeoffs suggest an intermediate optimum combination of cow size and carcass composition exists for matching cows with both a forage resource and the consumer demands. Producing cows or carcasses very distant from that optimum may compromise cow-calf production efficiency. If consumer demand for meat composition becomes extreme, then cow-calf producers can exploit specialized sire and dam lines through crossbreeding to meet those demands. In this way cow-calf producers need not sacrifice an efficient match between biological types of cattle and forage resources.

Tradeoffs in Growth, Fertility, and Body Composition Affecting Genetic Improvement of Beef Cattle

S. Newman, M.D. MacNeil, R.E. Short, J.J. Urick, T.C. Nelsen, and W.L. Reynolds

Introduction

Efficient beef production on the Northern Great Plains results from complex interactions between growth, reproduction, and body composition. Tradeoffs among growth-, fertility-, and composition-related traits that result from various selection strategies are largely unknown. It is these tradeoffs that hinder genetic improvement in profitability and efficiency of beef production. For example, selection for either more rapid growth or greater leanness may sometimes compromise fertility.

To assess tradeoffs among growth, fertility, and carcass traits, a "selection criteria study" (SCS) was started in 1975. Data collection ended in 1977. This study is unique because animals were not subject to imposed selection for any traits nor were mates identified by any particular strategy. These unique features broaden the applicability of the results and remove complications associated with selection. Immediate results from this research are estimates of heritabilities and genetic correlations. When the data are completely analyzed, the ultimate result will be a series of selection indexes incorporating tradeoffs between growth, reproduction, and composition. Using these equations to select breeding animals leads to desired genetic improvements in efficiency or profitability.

Methods

In 1975, 114 pregnant cows and 36 heifers were assigned at random to 10 breeding herds. All animals were linecross Herefords composed of various combinations of Miles City Lines 1, 4, 6, and 10. Bulls for 1976, 1977, and 1978 breeding seasons were chosen at random from a group of 59 linecross bulls born in 1975. After 1978, 2 year-old bulls born in the project were used. A 60-day breeding season was used, and all calves weaned at about 180 days of age in mid-October. All cows were managed under range conditions with winter supplement supplied as needed.

Weights were recorded at birth, weaning, at end of a 140-d postweaning test, and at slaughter. Carcass traits recorded included carcass weight, dressing percentage, longissimus muscle area (rib eye area), marbling score, and kidney, pelvic and heart fat. Female growth and reproduction data includes age at puberty, milk production, interval from calving to first heat, pelvic area, calving difficulty, breeding dates, pregnancy rate, and estimates of fatness.

Results

Published results thus far indicate that selection for growth traits or size will result in heavier animals up to 30 mo of age. The high genetic correlations of weight at 30 mo of age of the sire with growth traits of progeny indicate that selection for growth could occur until sires reach that age. Nelsen et al. (1986) indicated that genetic correlations among some traits change as animals become older. Therefore, measurements should be taken when the genetic correlation is the highest.

Results indicate that there is no advantage, however, in keeping sires to 30 mo of age to slaughter to obtain measurements, either for heritability or genetic correlations. Sufficient kidney, pelvic, and heart fat and sufficient fat over the rib eye were not present to make accurate measurements in the 30-mo-old animals, even though they gave the visual appearance that measurable quantities of fat were present. There is genetic variation for carcass traits that could be used if market conditions made it economically feasible.

Recent Publications

Nelsen, T.C., R.E. Short, J.J. Urick, and W.L. Reynolds. 1984. Genetic variance components of birth weight in a herd of unselected cattle. J. Anim. Sci. 59:1459.

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Beef Cattle Reproduction Research at Fort Keogh: A Historical Perspective

R.A. Bellows

"We see further and our vision is clearer only because we stand upon the accomplishments of our predecessors"
-L.E. Casida

Introduction

The formal beginning of reproduction research at this location was in April 1960. A cooperative study was approved involving the U.S. Range Livestock Experiment Station, the Montana Agricultural Experiment Station, and the American Breeders Service, Chicago, IL. The objective was to study problems related to artificial breeding of beef cattle under range conditions. But since the establishing of the research program at the Fort Keogh Laboratory in 1924, various reproduction studies and observations have been completed.

Early studies involved horses, mules, swine, sheep, and turkeys in addition to beef cattle. These early works were primarily breeding and nutrition studies, but reproduction information such as pregnancy rates, numbers of offspring produced, and birth weights were collected on all the species, plus fertility and hatchability data on turkey eggs. The beef cattle, horse, mule, swine, and sheep studies were initiated in 1925 with turkey research being added in 1929.

A cooperative project was initiated with the University of Missouri in 1937 to study estrus and ovulation in the mare. This work was expanded in 1938 to include methods of equine semen collection and artificial insemination. This work was not only pioneering equine research but also set the stage for scientific reproduction studies in all species of farm animals at many locations. These classical studies were conducted and published by F.N. Andrews and F.F. McKenzie.

During the period from 1935 through 1939, studies were conducted on infectious abortion (brucellosis) in cattle and equine encephalomyelitis in horses. The Laboratory was the first location to investigate methods to control brucellosis applicable to cattle under range and semi-range conditions. This work was under the direction of veterinarians from both Montana State University and the USDA. Recommendations were published in 1940 by H.H. Marsh and H. Welch. The encephalomyelitis study was the first to suggest a difference in genetic susceptibility in some breeds of horses and was published by W.V. Lambert and coworkers in 1939.

Studies on bloat were conducted in 1940-41. Results indicated that the incidence of bloat was markedly reduced when 50% of the barley in the ration was replaced by an equal amount of molasses dried beet pulp. The studies, which were published in 1943 by B. Knapp, Jr. and his coworkers, also identified that progeny of certain bulls had a greater incidence of bloat, and this could be identified by progeny testing.

The first formal paper on fertility of cattle from the Research Laboratory herds was published in 1944 by A.L. Baker and J.R. Quesenberry. Some of the recommendations made from this work are still applicable today: 1) individually identify cattle so effective culling can be made; 2) cull cows that fail to produce calves; and 3) test bulls for semen quality before the breeding season. This work was followed by papers on vaginal and uterine prolapse (1956) and on causes of stillbirths (1959). The latter two papers were authored by R.R. Woodward and coworkers.

F.J. Rice, a geneticist, was the first staff scientist to obtain project approval to conduct specific reproduction studies with cattle at this Laboratory. The project was initiated in 1960 with objectives to determine: 1) time of occurrence of the first estrus after parturition; 2) various methods of heat detection; and 3) calving percentages in herds bred artificially or by natural service.

The formal program in reproductive physiology started in 1962 under R.A. Bellows. Work was initiated to include studies on essentially all phases of reproduction in the female plus puberty studies in the male. Staff expansion occurred in 1967 with the addition of R.E. Short, whose research emphasis was in postpartum physiology. R.D. Randel and R.B. Staigmiller were added to the staff in 1971 and 1974, respectively. In 1970, construction of a new office-laboratory complex was completed allowing expansion of the research program into laboratory analyses for hormones controlling reproduction. This laboratory expansion was under the direction of Drs. Randel and Staigmiller.

Reproduction is the largest factor affecting efficiency of production in range beef cattle. The objective of reproduction research at this Laboratory has been to increase the efficiency of reproductive processes at all phases of the production cycle. The largest single reason that cows do not wean calves is because they fail to become pregnant during the breeding season. The second largest loss is due to calf deaths at or shortly after birth. These areas have received major emphasis in reproduction studies since 1962 involving both basic and applied approaches.

Increasing Reproductive Efficiency

Puberty. Replacement heifers make up approximately one in five females in the breeding herds of most ranches. Production of suitable replacements is an expensive process, and developing methods to reduce this cost and yet assure a high pregnancy rate are the objectives of the puberty research at this Laboratory. This work has shown that adequate nutrition from weaning to one year of age can increase conception rates up to 27%. By separating heifers into heavy or light groups based on their weaning weight and feeding to meet their nutrient needs, pregnancy rate was increased 19% in the first breeding season with no increase in total feed costs. Adding monensin to the ration during the first wintering period following weaning hastened puberty, and feeding heifers for maximum skeletal growth resulted in larger pelvic openings and a reduction in calving problems. Use of zeranol (Ralgro**7**) implants increased rates of gain in both heifers and bulls but reduced pregnancy rates in heifers and testicle size and semen production in bulls. This compound must be used with caution in animals that are potential breeding animals.

Up to 22% of all replacement heifers exhibit a nonpuberal estrus at some time prior to reaching puberty. This estrus is not fertile since the heifer does not ovulate. The condition is not abnormal since the subsequent pregnancy rates following its occurrence are the same as in heifers in which it was not observed.

Recent work at this Laboratory has shown that heifers bred at their third postpuberal estrus had a 21% higher conception rate than did heifers that were bred at their puberal estrus.

Embryo transfer has been used to determine the mechanisms controlling this effect and has revealed the pregnancy maintenance capabilities of the uterus in the puberal heifer are inferior to those of the older animal. This work clearly shows that the replacement heifer should be cycling prior to the beginning of the breeding season if we are to obtain maximum conception rates.

Basic research studies have been conducted at this Laboratory to determine hormone changes prior to and at puberty. Puberty was successfully induced by mimicking the changes through hormone administration. Detailed chemical analyses of heifers slaughtered at puberty revealed that puberty did not occur at a constant body composition. The roles of melatonin and thymosin in attainment of puberty are also being studied. Research in these areas will result in a more in-depth understanding of the basic mechanisms controlling puberty and will play a key role in developing management systems to assure early conception.

Research on puberty in bulls has also been conducted at this Laboratory. Age at attainment of production of 100 million sperm and age when the bull was capable of successful mating were determined in straightbred and crossbred animals. Angus bulls were the youngest at puberty, and crossbred bulls reached puberty and attained successful mating ability at younger ages than did straightbreds.

Calving difficulty. Calf losses at birth result in a major reduction in the net calf crop. Data from this Laboratory show that 60% of these losses are due to dystocia (defined as delayed and difficult birth) and at least 50% of these calf deaths could be prevented by giving timely obstetrical assistance. Laboratory studies have shown dams that experience rapid completion of calving (labor) had pregnancy rates 13% higher than did dams in which labor was prolonged. Additionally, calves that experienced rapid birth gained 7 to 12% faster from birth to weaning than calves experiencing prolonged labor. Research from this Laboratory was the first to conclusively establish that calf birth weight is the most important factor affecting dystocia. Calf birth weight is the result of fetal growth while in the uterus and is affected by the genetic growth potential and the maternal uterine environment. The fetal growth potential can be modified by crude protein or energy content of the gestation diet which alters the blood metabolite levels of the dam, but the effect on dystocia is neither predictable nor large. Exercise during the last trimester of gestation did not affect incidence or severity of dystocia but markedly increased feed requirements of the dam. Exercise resulted in a 14.8% increase in pregnancy rate in the subsequent breeding season. Laboratory scientists were the first to demonstrate the effects of fetal genotype x maternal environment interaction on fetus weight. Some maternal environments seem to complement fetal growth while others suppress it.

Research from this Laboratory has found that precalving hormone changes in heifers that experience dystocia differ from those that calve without difficulty. This adds a new dimension to dystocia causes and indicates that high birth weights and hormone abnormalities acting separately or together can affect the incidence and severity of dystocia. Testosterone (the male sex hormone) concentrations at 231 days of gestation in the peripheral circulation of the dam gestating a male fetus are higher than in dams gestating a female fetus. Treatment of the pregnant heifer with porcine relaxin had no effect on precalving changes in the birth canal of the dam or incidence or severity of dystocia. An electronic calving monitor is being developed to determine maternal and fetal stress during calving and relate this to calf survival and length of the postpartum interval to estrus and rebreeding in the dam. These studies are important since they are leading the way for developing methods to reduce the $800 million calf and cow loss that occurs each year at calving in the nation's beef herds.

Postpartum reproduction. Timely rebreeding of the cow herd is a necessary prerequisite to profitability, and this is highly dependent on the length of the interval elapsing from calving to first estrus. Suckling by the calf has a major prolonging effect on this interval. The interval can be shortened by high levels of feeding, weaning the calf, or by surgical removal of the mammary gland. Additional research from this Laboratory revealed that suckling prolonged the postpartum interval by inhibiting the pulsatile release of luteinizing hormone from the pituitary gland of the cow. The effect of weaning was mimicked by giving low-dose injections of gonadotropin releasing hormone (GnRh) every 2 hours, but the effectiveness of the GnRh injections was dependent on whether the cow was fat or thin. These findings provided new information on the mechanisms controlling the postpartum interval and emphasized the role of adequate nutrition for successful postpartum reproduction in the cow. Basic studies have attempted to further determine how such effects as feed level, suckling, and steroid-hormone feedback control the release of pituitary hormones. The nervous system may be a part of this control through production of endogenous opioid peptides(EOP). Results from this Laboratory indicate that EOP do have a limited role during the estrous cycle but little effect during the postpartum period.

Reproduction-nutrition. Cows failing to rebreed or rebreeding late in the breeding season result in a 15 to 25% reduction in the potential pounds of calf weaned per cow exposed to the bull. Research from this Laboratory has shown the major cause of this reduction to be inadequate nutrition during one or both of two critical nutritional periods. The first critical period is during the last 3 months of pregnancy, and the second is during the time from calving until adequate forage is available to meet the nutrient demands of the lactating dam. Research results from this Laboratory show that having cows attain a minimum body condition score of 5 at calving is an excellent method to assure that nutrient requirements have been met during gestation and that some body reserves are available in the dam that can be utilized during the time period from calving until adequate forage nutrients are available to meet her needs.

Artificial insemination. Laboratory research has been conducted on estrous synchronization. Results to date show a combination of a progestogen, either implanted or fed, with injected prostaglandin is the most promising. Research from this Laboratory has also shown that conception rates from artificial insemination (A.I.) can be increased over 6% in cows by manual massage of the clitoris for 3 seconds following completion of routine A.I.

Studies on synchronization of estrus and artificial insemination in swine have been conducted at this Laboratory. Estrus was successfully synchronized with a synthetic progestogen, and litter size was greater in females bred by natural service than in those bred artificially with frozen-thawed semen. Conception rates were not improved by mating the female to a vasectomized boar immediately following A.I. This work was under the direction of V.G. Pursel, USDA-ARS, Beltsville, MD.

Multiple births. Successful production of twin and triplet calves from beef cows or heifers has been accomplished at this Laboratory. This research was the first to successfully combine synchronization of estrus and gonadotropin superovulation treatments. Calf crops up to 119% were produced following a single breeding-treatment sequence compared to 70% in untreated controls. The calves were artificially reared on cold whole milk or cold milk replacer plus grain and hay. Unrelated twins have also been produced by transferring an embryo into a cow that had been bred naturally 8 days prior to the transfer. Genetic markers were used so the natural and transferred calves could be identified. In another study, an embryo was collected from a Holstein donor cow in Beltsville, Maryland, placed in the uterus of a live rabbit and shipped to this Laboratory. The embryo was flushed from the rabbit uterus on day 7 and the embryo transferred to the uterus of a recipient Brahman-cross cow resulting in the birth of a normal Holstein calf 281 days later.

Ovarian response to superovulation treatments has been studied in cows given pituitary extracts from swine, sheep, or horses or given a dimeric follicle stimulating hormone produced from bovine anterior pituitary cells through recombinant DNA technology. Results uniformly indicated variability in ovarian response was a typical characteristic regardless of gonadotropin used or treatment sequence.

Follicle-oocyte. Laboratory research on superovulation has led to basic studies of the ovarian follicle and the oocyte. This work has helped define the difference in follicular function associated with a viable oocyte (nonatretic follicle) compared to a nonviable oocyte (atretic follicle). These findings showed that visual appraisal of the nuclear configuration of the cells was not an accurate means of determining oocyte quality or maturation. Additionally, this work showed the total dependence of the oocyte on intercellular exchange with other cells to achieve developmental competence. Portions of this work involved aspiration of oocytes from ovarian follicles both in vivo and in vitro and in vitro fertilization and maturation. These studies can potentially result in an unlimited supply of embryos for transfer, storage, or genetic manipulation. As secrets of the follicle are unlocked, results can assist in determining why approximately 35% of the matings in a cattle population do not result in a viable pregnancy.

Pine needle-induced abortion. Abortions in cattle are commonly the result of disease conditions. Abortion can be induced in cattle and buffalo, but not sheep or goats, by feeding needles from Ponderosa pine. These findings, based on research from this Laboratory, show that the abortion response is dependent on stage of pregnancy when fed, amount of needles fed, and duration of feeding. Three to four pounds of dried needles fed daily for 7 days during late pregnancy resulted in essentially a 100% abortion rate. Nutritional variables such as feed level, ration protein content, or various supplements, including vitamin A or bentonite, did not affect the response. Cooperative work with scientists at Iowa State University has identified the mechanism of action to be that of the abortifacient compound reducing the blood flow to the placental caruncles by 80%, thus creating fetal stress and initiating a normal parturition sequence. Incidence of retained placenta and calf mortality are high due to the calf being premature at birth. Recent results indicate major progress is being made on identification of the abortifacient compound.

The Future

Since successful reproduction will remain a critical component of profitable and sustainable beef production, research on mechanisms controlling reproductive processes will continue at this Laboratory. Puberty research will emphasize maximizing conception rates in the young female. Additional research will be directed toward determining the reasons for the marked increase in pregnancy rate that occurs in heifers bred at their third vs first estrus. Dystocia research will determine the effects of sire, dam, and nutrition on prepartum hormone changes and how these are related to labor patterns, heart rate of the dam and fetus, and body temperature changes in the dam. Results will be related to calf survival and gains and subsequent reproductive performance of the dam. Research on pine-needle induced abortion will identify the abortifacient compound. Once the compound is identified, methods of counteracting or neutralizing its effects will be determined. Management systems based on controlling all phases of the reproduction cycle will be developed. These systems will be designed to increase production efficiency and make major contributions toward assuring sustainability of beef production from the range resource well into the 21st century.

Individuals Associated with Reproductive Research at Fort Keogh

Individual	Years at Fort Keogh	Position
R.A. Bellows	1962 - present	Reproductive Physiologist
R.E. Short	1967 - present	Reproductive Physiologist
R.D. Randel	1971-1974	Reproductive Physiologist
R.B. Staigmiller	1974 - present	Reproductive Physiologist
Current Reproduction Research Support Staff		
D.A. Phelps	1981 - present	Research Associate
M.E. Woods	1988 - present	Farm/Ranch Hand
W.R. Harris	1974 - present	Farm/Ranch Hand
R.A. Charles	1989 - present	Farm/Ranch Hand
S.E. Bartlett	1992 - present	Bio. Lab Technician
J.B. Hall	1991 - present	Post Doctorate

Dystocia Research

R.A. Bellows

Introduction

Two projects have been completed recently: 1) effects of exercise of the pregnant dam on dystocia and rebreeding; and 2) effects of sire and maternal environment on fetal growth.

Methods

Study 1. Forty-four heifers and 74 cows bred to a single Charolais bull were assigned to either restricted (R) or forced (F) exercise for the last 90 days prior to calving. R dams were held in feedlots 90' X 190' (25 to 29 animals per group) and maintained on hay and grain fed to supply 10.1 lbs TDN per head daily. F dams received the same hay and grain fed to give weight changes approximating R dams. Pregnant dams were weighed at 14-day intervals, and feed levels were adjusted as needed. F dams were fed 1 mile from the only water source in the pasture resulting in a forced walk of 2 miles daily from the feeding area to the water and return. Observation indicated that all dams walked the 2 miles at least once daily. F dams were placed in the feedlots on a weekly basis on days 260 to 267 for calving. Calvings were observed 24 hr daily by experienced herdsmen; calving scores from 1 (no assistance) to 4 (major assistance including cesarean section) were given to each calving.

Calves were dehorned, male calves were castrated, and calves were weighed within 12 hr after birth. Pairs were moved to a crested wheatgrass pasture within 72 hr after birth. Alfalfa hay and 4.5 lbs pelleted grain were fed daily until May 17. Pairs were then moved to native range, and all supplemental feeding was terminated. Estrus was determined with sterile bulls wearing marking harnesses during the prebreeding period. Breeding was by A.I. for 45 days from June 15 to July 30. Pregnancy was determined on October 12.

Study 2. Fetal genotype x maternal environment interaction effects on fetal growth were studied in F_1 heifers produced by mating Brahman (B), Charolais (C), Jersey (J), Longhorn (L), or Shorthorn (S) sires to crossbred cows. The F_1 heifers were then mated to one of two Angus bulls selected to produce high (H) or moderate (M) fetal growth. All pregnant dams were slaughtered at 231 days of gestation. Blood samples were obtained from the dam for 3 days before and the day of slaughter. Pelvic measurements and body weights of the dam and detailed fetal and placental measurements were obtained at slaughter as were complete carcass measurements of the dam.

Results

Study 1. Data are summarized in Table 1. Exercise had no significant effects on gestation length, dystocia severity or incidence, postpartum interval, or numbers showing estrus by the beginning of the breeding season. However, F dams required more breedings per conception, and exercise resulted in a 14.8% increase in pregnancy. F dams required 31% more feed than the R dams.

Table 1. Effects of exercise on dystocia and rebreeding.

	Calving difficulty							
	No. animals	Gest. length (days)	Calving diff.		Int. calv. to 1st estrus (days)	Estrus by begin breed. (%)	Breed./Preg. concept.[a](%)	
Group			Score	Incid.(%)				
Exercise								
Restricted	54	276.4	1.5	26.7	62.6	75.7	1.17	76.3
Forced	57	276.0	1.4	22.4	60.6	71.0	1.44**	91.1*

[a] Calculated on pregnant only; * $P < .05$; ** $P < .01$.

Study 2. Dam data summarized in Table 2 show B and S dams were the heaviest while J and L were the lightest. Pelvic area differences were not significant. Intact fetus weights were greatest in C, membrane weights highest in B, and there were more placentomes in B dams.

Table 2. Dam differences.

Item	No. animals	Live wt. (lb.)	Pelvic area (cm^2)	Intact fetus wt. (lb.)	Placental membrane wt. (lb.)	Placentome no.
F_1 dam breed:						
Brahman	6	1,021	265	40	3.3	121
Charolais	8	1,010	270	47	2.4	108
Jersey	7	946	248	41	2.2	87
Longhorn	14	917	262	42	2.0	100
Shorthorn	11	1,025	258	45	2.3	117
Significance		**	C	H	**	H

H $P < .10$; ** $P < .01$.

The sire x dam interaction effect on eviscerated fetus weight (Table 3) shows B dams allowed the fetus to express its sire growth difference but at a lower level. J dams allowed the high-growth fetus to express its near-maximum growth potential.

Table 3.Sire x dam differences in eviscerated fetus weight (lb.)[a].

Breed F_1 dam	No. animals	Moderate growth sire	No. animals	High growth sire
Brahman	3	30	3	36
Charolais	3	36	5	39
Jersey	3	27	4	39
Longhorn	7	34	7	35
Shorthorn	6	35	5	38

[a] Significance of interaction, $P < .05$.

Dam blood testosterone concentrations are summarized in Table 4. Concentrations were greatest in dams gestating fetuses sired by the high-growth sire and in dams gestating male fetuses. We are presently studying whether these findings are of value in predicting dystocia.

Table 4. Testosterone concentrations at 231 days of gestation.

Item	Testosterone (pg/ml)
Sire growth potential	
Moderate	64
High	87H
Fetus sex	
Female	52
Male	99**

H $P < .10$; ** $P < .01$.

Conclusions

Study 1. We speculate that higher feed intake of the F dams during gestation created greater gut capacity subsequently allowing greater forage intake on pasture which resulted in the higher pregnancy rate; or there may have been body composition differences due to exercise that resulted in greater pregnancy. This finding is similar to data in dairy cattle and suggests physical activity has a positive effect on rebreeding.

Study 2. Results show that some maternal environments suppress fetal growth while others seem to complement it. This helps explain some of the differences in "sire" effects on birth weight noted in different herds.

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Hormonal Advancement of Puberty In Heifers

J.B. Hall, R.B. Staigmiller, R.A. Bellows, R.E. Short, S.E. Bartlett, and D.A. Phelps

Introduction

Raising replacement heifers is an expensive segment of the beef enterprise. Heifers that conceive early in their first breeding season are more productive on a yearly and lifetime basis than heifers that conceive late in the breeding season. Previous research at Fort Keogh has revealed that first service conception rates are greater in heifers bred at the third rather than pubertal estrus. Therefore, heifers must reach puberty several months before the breeding season for maximum production efficiency and increased return on investment.

Research at Fort Keogh and other locations has demonstrated that puberty can be induced in beef heifers by treating them for 7 to 10 days with progestins (Syncro-mate B or MGA). However, responses to progestins can vary depending on variations in age or weight, and we do not understand which of these factors (age or weight) is the most important. Although cattle are not seasonal breeders, it has been shown that day length can influence age at puberty in heifers. Melatonin is a hormone produced in the brain of animals that relays information on length of the day. Recently, researchers in West Virginia gave melatonin to beef heifers, and they reached puberty (started to cycle) earlier than untreated heifers. It is not known if timing of the melatonin treatment with respect to natural day length is important.

As these two naturally occurring hormones may offer a practical way to reduce age at onset of puberty in beef heifers under range conditions, we designed 2 experiments with the objectives: 1) to understand the relationship between age and weight in the ability of a progestin to induce puberty in beef heifers; and 2) to examine if timing of melatonin treatment effects advancement of puberty onset in beef heifers.

Methods

Experiment 1. Heifers were allotted by weaning weight to either a high gain diet or a low-high gain diet. Heifers consuming the high gain diet gained 2.0 lbs per day. Low-high gain heifers gained 0.9 lbs for the first 90 days of the experiment and then gained 2.0 lbs/ day to parallel the gains of the high gain heifers. This gain strategy was intended to insure low-high gain heifers would reach a given weight 45 days after the high gain group did. Six high gain and 6 high-low gain heifers were treated with progestin: 1) immediately prior to switch low-high heifers to 2.0 lbs/day gain; 2) 45 days after treatment 1; and 3) 45 days after treatment 2. Heifers were implanted with an ear implant containing 6 mg of progestin for 10 days. Only prepubertal animals that had never received progestin were treated, so no animal received two treatments. Heifers were observed for estrus and checked by ultrasound for a functional corpus luteum (CL).

Experiment 2. Twenty-four spring-born and 24 fall-born heifers were treated with either 35 mg of a sustained release (110 day) melatonin implant or an injection of corn oil vehicle. Implants consisted of melatonin bound to microspheres. Spring-born heifers were given melatonin on September 24, 1992 (about the time of the autumnal equinox), and fall-born heifers were implanted on March 12, 1993 (about the time of the spring equinox). Both spring- and fall-born heifers were 5 months old when implanted.

Results

Experiment 1. The numbers of heifers in heat within 5 days of removal of the progestin implant are summarized in Table 1. Two high gain heifers (1 at 9.5 and 1 at 11 months of age) became ill, due to causes unrelated to implanting, shortly after the treatment period, and results from these animals were not included. At 12.5 months of age only 10 high gain heifers remained that had not been implanted or reached puberty spontaneously. A greater number of heifers responded to the treatment at 12.5 months than at any other time. In addition, at 12.5 months more low-high gain heifers responded to treatment than high gain heifers at 11 months of age even though weights between 12.5 month old low-high heifers and 11 month old high heifers were similar. These results suggest that age may be a more important factor than weight in the responsiveness of heifers to puberty induction with progestins.

Table 1. Number of heifers attaining puberty within 5 days of removal of progestin implant.

	High gain			Low-high gain		
Age (months)	Weight	Progestin	Control	Weight	Progestin	Control
9.5	640.9	0/5	0/6	566.1	0/6	0/6
11	763.8	0/5	1/6	654.5	1/6	0/6
12.5	837.1	4/5	2/5	781.7	5/6	0/6

Experiment 2. The cumulative percentage of spring-born heifers having attained puberty by month are presented in Table 2. No data are available yet on the fall-born heifers as the experiment has not been completed.

Table 2. Effect of melatonin on percentages of spring-born heifers reaching puberty.

	Percent Pubertal	
Month	Melatonin (n=12)	Control (n=10)
January	8	30
February	8	40
March	25	60
April	25	60
May	42	70

Fewer melatonin-treated heifers had attained puberty during the period from January through April compared to control heifers. The melatonin implant expired in late January. Apparently, treatment of spring-born heifers with long acting melatonin in the fall delays the onset of puberty. The results of our experiment are in stark contrast to those previously reported in which spring-born heifers treated with melatonin for 35 days during the summer attained puberty earlier than control heifers.

Conclusions

The results from Experiment 1 provide further evidence that puberty can be induced in beef heifers with progestins and that age of the heifers is critical in determining the success of puberty induction. A 7 to 10 day administration of progestin to heifers between the ages of 12 and 13 months may be an effective way to induce early puberty and increase the number of estrous cycles prior to the breeding season.

Administration of melatonin to young heifers can alter the age at puberty onset. However, the effects of melatonin may depend on the timing and length of administration. Further research is needed before this technology may be applicable to beef production systems.

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Studies on Production of Embryos

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

Introduction

Embryo transfer has become an important part of the beef cattle industry. Its primary purpose is to increase the number of offspring that can be obtained from highly desired genetic stock. A key element in the success of embryo transfer is the economical production of large numbers of high quality embryos for transfer. In the past the procedure for producing embryos has involved extensive handling of the animals: giving a series of 8 injections of hormone to induce them to ovulate more than 1 egg. The following studies were conducted to establish procedures to reduce the amount of animal handling required by reducing the number of injections.

Methods

Study 1. Twenty cows were divided into 2 equal groups. One group received the required amount of hormone in the normal 8 injection scheme, and the other group received the same amount of hormone in a single injection. All cows in both groups also received an injection of Lutalyse to make them show estrus (heat) at the appropriate time. The cows were bred and embryos recovered by flushing the uterus nonsurgically with fluid 7 days after breeding. For each cow the number of ovulations was determined, and the embryos were classified as either viable or nonviable.

Study 2. Twenty cows were treated exactly the same as those in the first study. However, the cows were genetically different in the two studies, and the studies were done at different times of the year. Hence, differences in the results could be due to either genetics or unknown seasonal effects.

Results

The number of ovulations and the number of viable embryos produced in the two studies are shown in Table 1 below. The factor that is most important to us in this study is the number of viable embryos that are produced. Note that the results differ between the 2 studies. In the first study, there was essentially no difference between the 2 injection schemes, but the overall response to both schemes was quite low. In the second study, the response was much better in even the single injection, but the multiple injections resulted in considerably more viable embryos. It is not clear why the 2 genetic groups of animals responded differently, and this may well be the basis of further studies.

Table 1. Superovulation response in cows receiving single vs multiple injections of FSH.

Study	Number of injections	Number of ovulations	Number of viable embryos
1	1	10.6	1.7
	8	9.3	1.2
2	1	12.2	3.6
	8	21.2	11.2

Conclusions

What is clear is that the single injection scheme **as we used it** is not an acceptable means of inducing multiple ovulations for the generation of embryos. In the course of this study, an ultrasound unit was used to monitor the development of the follicles that ovulate and provide the eggs for fertilization. There was evidence in the ultrasound data that follicles began development with the single injection, but full development was not achieved. If this is the case, it is likely that the eggs ovulated were of poor quality and resulted in either lack of fertilization or in non-viable embryos. We will conduct further studies to determine if a different injection regime, still with fewer injections and reduced animal handling, can result in satisfactory production of embryos.

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Body Composition at Puberty in Beef Heifers as Influenced by Nutrition and Breed

J.B. Hall, R.B. Staigmiller, R.E. Short, R.A. Bellows, S.E. Bartlett, and D.A. Phelps

Introduction

Heifers that conceive early in their first breeding season will produce more pounds of calf per year and during their lifetime than heifers that conceive late in the breeding season. Previous research at Fort Keogh has revealed that first service conception rates are greater in heifers bred at the third rather than pubertal estrus. Therefore, heifers must reach puberty several months before the breeding season for maximum production.

Age at puberty in heifers can be influenced by both nutrition and breed. However, the mechanism by which nutrition and breed affect age at puberty is unknown. Researchers have suggested that a critical level of body fat or a particular body composition may be necessary for puberty onset in livestock. In addition, beef producers are concerned that breeding leaner cattle may result in heifers that do not have enough body fat for reproduction.

The objective of this study was to determine if body composition at puberty was the same in heifers differing in breed and reared on different diets.

Methods

Thirty-one crossbred heifers sired by Charolais (Charolais x; n = 15) or Hereford (Hereford x; n = 16) bulls were assigned by weaning weight to high (H; 2.2 lbs/d) or moderate (M; 1.3 lbs/d) gain diets at 7 mo of age. Heifers were full-fed complete mixed rations in drylots. Heifers were weighed every 28 d, and rations were evaluated for adequacy to maintain the appropriate gains every 56 d. Rations were altered as necessary to meet NRC requirements for growing heifers gaining either 2.2 or 1.3 lbs/d.

Heifers were penned with androgenized steers fitted with marking harnesses to assist in detection of estrus. Puberty was defined as estrus followed by formation of a functional corpus luteum (CL). Presence of a CL was determined using ultrasound echography, and functionality was indicated by serum progesterone concentrations that exceeded 1 ng/ml.
Between 10 and 18 d after pubertal estrus, body weight, hip height, heart girth, body condition score, and ultrasound backfat thickness measurements were obtained as indirect estimates of body composition. All heifers were slaughtered within 20 d of pubertal estrus. At slaughter the weight of blood, head, hide, rumen (empty), intestine (empty), liver, omental fat, udder fat, remaining offal (shanks, hooves, spleen, etc.), and hot carcass were obtained, and these weights were used to calculate empty body weight. All non-carcass constituents were pooled, ground, and subsamples taken. Rib eye and fat thickness over the rib eye measurements as well as weights of edible trim, bone, and kidney fat were obtained 72 hr after slaughter. Edible trim and bone measurements were taken from the right side of the carcass. The carcass was divided into the edible and inedible pools, and these pools were ground and subsamples taken.

Subsamples from the non-carcass and edible- and inedible-carcass pools were analyzed directly for fat, ash, and moisture to determine empty body composition. The remainder of the pool was considered fat-free organic matter (FFOM) and was determined by subtraction.

Data were analyzed by a 2-way analysis of variance using the general linear model (GLM) procedure of the Statistical Analyses System (SAS). Main effects were dietary energy level and breed of sire. All main effects and the 2-way interaction were tested for significance.

Results

Age at puberty and body measurements. Puberty and body composition data are summarized in Table 1. Heifers consuming the high gain diet were younger and heavier at puberty than moderate gain heifers. Breed did not influence age at puberty, but Charolais heifers were heavier at puberty than Hereford animals. Skeletal dimensions at puberty were greater in high gain than moderate gain heifers as indicated by greater hip height and larger heart girth measurements. Charolais x heifers were taller and had a greater heart girth than Hereford x heifers. High gain heifers had greater ultrasound backfat thickness and higher body condition score and weight to height ratio than moderate gain heifers. Ultrasound backfat thickness and body condition score were not affected by breed, but Charolais x heifers had greater weight to height ratio than Hereford x heifers.

Table 1. Age, indirect and direct estimates of body composition, and empty body composition at puberty in beef heifers.

Item	Treatment				
	High gain diet	Moderate gain diet	Charolais x	Hereford x	SEM
Number of animals	15	16	15	16	
Age at puberty (d)[a]	386.0	415.6	406.2	395.3	11.9
Preslaughter measurements					
Weight (lbs)[d]	876.6	747.6	888.2	737.9	24.9
Hip Height (in) [d,g]	48.2	46.8	49.6	45.5	.55
Heart girth (in) [d,f]	68.7	64.2	68.2	64.7	.7
Body condition score [d]	6.6	5.8	6.4	6.0	.2
Backfat thickness (in) [a]	.26	.2	.24	.23	.02
Weight/height ratio [d,f]	3.2	2.8	3.2	2.9	.1
Slaughter measurements					
Carcass weight (lbs)[c,f]	508.4	413.1	511.7	410.1	16.1
Non-carcass (lbs)[c,f]	262.8	231.3	265.2	228.88	8.2
Rib eye area (in^2)[d,g]	10.3	8.8	10.4	8.8	.28
Backfat thickness (in)[d,e]	.27	.17	.24	.20	.02
Edible trim (lbs)[d,f]	366.9	296.3	364.6	298.5	5.3
Inedible trim (lbs)[f]	141.9	112.4	149.5	100.1	5.5
Empty body composition					
Moisture (lbs)[c,e]	423.5	370.2	436.3	357.6	11.7
Fat (lbs)[c]	177.0	123.0	166.4	133.6	13.2
Ash (lbs)[e]	30.4	26.2	31.9	24.7	2.0
FFOM (lbs)[c,e]	140.9	119.5	144.6	115.7	3.8
Moisture (%)[b]	55.3	58.1	56.4	57.0	.7
Fat (%)[b]	22.3	19.1	20.7	20.7	1.0
Ash (%)	3.4	4.1	4.1	3.9	.2
FFOM (%)	18.5	18.7	18.7	18.4	.6

[a] Effect of diet (P < .08).
[b] Effect of diet (P < .001).
[c] Effect of breed (P < .001).
[d] Effect of breed (P < .01).
[e] Effect of diet (P < .01).
[f] Effect of breed (P < .05).
[g] Effect of diet (P < .05).

Slaughter and carcass. At slaughter the weight of the carcass and non-carcass components was greater for high gain heifers than for moderate gain heifers. Within the non-carcass component there were greater weights of blood, liver, heart and lung, omental fat, hide, and remaining offal than that of moderate gain heifers (Table 2). Carcasses of high gain heifers had larger rib eye areas, more backfat, and contained more edible trim than carcasses of moderate gain heifers. The weight of carcass and non-carcass components was greater for Charolais x heifers than Hereford x heifers. Charolais x heifers had greater amounts of blood, head, liver, heart and lung, intestine, hide, and remaining offal in the non-carcass component than Hereford x heifers (Table 2). Charolais x heifers carcasses had larger rib eye area, greater backfat, and more edible and inedible trim than carcasses of Hereford x heifers. When slaughter data were analyzed as a percentage of liveweight, high gain heifers had more omental fat, carcass weight, edible trim and backfat, and less rumen and intestine than moderate gain heifers (data not shown). As a percentage of liveweight, Charolais X heifers had less non-carcass and more carcass weight than Hereford X heifers.

Table 2. Mean weights of various non-carcass components of beef heifers at puberty.

	Treatment				
Item	High gain diet	Moderate gain diet	Charolais x	Hereford x	SEM
Number of animals	15	16	15	16	
Blood (lbs)[a,b]	26.7	22.9	26.4	23.2	.9
Head (lbs)[b]	25.4	24.3	26.5	23.2	.7
Liver (lbs)[a,b]	11.0	9.3	11.0	9.3	1.1
Heart and lungs (lbs)[a,b]	13.2	11.0	13.2	11.0	4.4
Omental fat (lbs)[a]	15.6	9.0	13.2	11.2	.9
Rumen, empty (lbs)	39.5	39.9	42.1	37.5	1.8
Intestine, empty (lbs)[b]	14.8	15.0	15.6	14.1	4.4
Hide (lbs)[a,b]	75.2	66.6	75.2	66.6	2.6
Remainder (lbs)[a,b]	44.5	33.3	41.9	35.9	2.0

[a] Effect of diet ($P < .05$).
[b] Effect of breed ($P < .05$).

Chemical composition. Heifers consuming the high gain diet had more pounds of moisture, fat, and FFOM in the empty body at puberty than moderate gain heifers (Table 1). As a percentage of empty body weight, high gain heifers had less moisture and more fat than moderate gain heifers. The empty body of Charolais x heifers contained more moisture, ash, and FFOM than that of Hereford x heifers. As a percentage of empty body weight, breed did not influence composition at puberty.

Conclusions

Heifers fed the high gain diet were younger and heavier at puberty than heifers consuming the moderate gain diet. Greater amounts of backfat and internal fat, and higher condition score, and weight to height ratio indicate that high gain heifers were fatter at puberty. Larger carcass weight, rib eye area, and amount of edible trim in high gain heifers suggest greater lean tissue deposition. Furthermore, our study demonstrates that whole animal empty-body chemical composition at puberty was different between the two dietary treatments. Also, differences in carcass data and chemical composition are not merely a function of increased liveweight as a percentage of carcass weight, moisture, and fat were different among high gain and moderate gain heifers.

Breed of sire did not influence age at puberty. However, the larger carcass mass in addition to increased amounts of moisture, ash, and FFOM in Charolais x compared to Hereford x heifers may indicate greater amounts of lean tissue and bone in Charolais x heifers at puberty. In addition, Charolais x heifers apparently partitioned nutrients differently than Hereford x animals as more of the liveweight of Charolais x animals was represented in the carcass rather than the non-carcass portion of the animals.

Results from this study confirm previous observations that nutrition alters body composition at puberty. In addition, our data provide the first chemical analysis of empty-body composition of heifers at puberty, and these direct measures of composition were consistent with indirect measures of body composition. Since high gain heifers were younger than moderate gain heifers at puberty and differed from M heifers in amounts and/or percentages of fat and fat-free organic matter at puberty, we conclude that puberty did not occur at a constant body composition in beef heifers.

Pine Needle Abortion in Cattle: Current Research

R.E. Short, D.A. Phelps, R.A. Bellows, R.B. Staigmiller, J.Rosazza, and S.P. Ford

Introduction

Needles from Ponderosa pine trees cause cattle to abort if the needles are consumed during late pregnancy. The effect is actually a premature parturition rather than abortion in that the mechanism of action involves constriction of the maternal caruncle arterial bed, resulting in a profound decrease in uterine blood flow, stress to the calf, and an induced parturition. Forage digestibility and rumen function are affected by pine needle ingestion, but these effects apparently are unrelated to the abortifacient effect. Not all cows that graze in areas of Ponderosa pine abort. Therefore, there must be conditions in which either cows do not eat pine needles or the needles have no effect if they are consumed.

The following experiments were conducted to determine the effect of some dietary variables and amount of needles consumed on response of cows and to further explore mechanism(s) and identification of active compounds. This research is partially funded by a unique cooperative grant from USDA that was originally awarded for 1989 to 1991 and then was renewed for 1992 to 1995. Iowa State University is the recipient of the grant that includes subcontracts to University of Iowa and Ft. Keogh LARRL, USDA. ISU is responsible for assays and blood flow studies, U of I for extraction and identification studies, and Fort Keogh for cattle studies and collection of plant material.

Methods

Pine needles (PN) were collected from mature Ponderosa pine (*Pinus ponderosa*) trees in Custer County, MT. Live trees were cut during the winter. Needles were collected by stripping at the time the trees were cut or by cutting branches and stripping needles after allowing them to dry. Air-dry needles were ground through a hammermill with a 2.25-cm screen and mixed (4.5 lbs per head per day) with the base diet at the time of feeding, or the needles were fed free choice in a separate bunk. Cows fed pine needles that aborted were injected with 20 mL of an antibiotic (Penstrep**7**) each day for 3 d after calving to prevent complications from retained placenta. Breeding dates were known so that feeding pine needles could be started at 250 d of pregnancy (range = 247 to 253).

Experiment 1. This experiment was conducted to determine whether buffalo would abort after eating pine needles from the same collection as that fed to cattle. The portion of this experiment involving buffalo was conducted at the National Bison Range, Moise, MT. The pastures used by buffalo at this location include Ponderosa pine at higher elevations and on southern slopes. No problems with calving rates or abortions had been observed. Cows in this herd normally calve in late April and early May. A herd of buffalo was gathered on April 1, and cows were rectally palpated for pregnancy. The first 12 that were confirmed pregnant were assigned at random to be fed ground pine needles (4.5 lbs/head) and hay (6 head) or a control diet of hay only (6 head). Cow age was estimated to range from 3 to 8 yr, and the estimated stage of pregnancy was 230 to 260 d.

The cattle portion of this experiment was conducted at the Fort Keogh Livestock and Range Research Laboratory, Miles City, MT. Eighteen cows were assigned to be controls or fed pine needles (4.5 lbs/head). The pine needles were from the same collection batch that were used for the buffalo.

Experiment 2. This experiment was conducted to determine the effects of protein content of the base diet and availability of a salt-sulfur block on abortion response when pine needles were available free choice. Fifty-eight cows were assigned to 1 of 6 treatments summarized in Table 2. Treatments 1 and 2 were negative (only hay) and positive controls (PN mixed with hay), respectively, and the remaining 4 treatments had PN available free choice and were arranged in a 2^2 factorial with the factors being adequate or high protein (AP vs HP) and no salt block or a salt-sulfur block available free choice.

Experiment 3. Differences in diet components do not affect response to PN when the PN are mixed in the diet, but diet differences may affect the consumption of PN when they are fed free choice. This experiment was conducted to determine the effects on abortion rate when PN were fed free choice with a silage-based vs a hay-based diet and the diets either limit fed or fed free choice. Forty-three cows were assigned to one of five treatments summarized in Table 3. Treatment 1 was a negative control with the remaining four treatments arranged as a 2^2 factorial.

Experiment 4. The effect of PN is to decrease blood flow to the uterus. Biological systems such as this can sometimes compensate if given appropriate stimuli. We hypothesized that this system would adjust to PN if PN were fed at a subthreshold level for a period of time. Previous studies established that 1.5 lbs/head/d was the threshold level. Thirty cows were assigned to 4 treatments as summarized in Table 4. Treatments 1 and 2 were negative and positive controls, respectively. Treatments 3 and 4 were fed as in Treatment 2 except that they were prefed low levels (.25 or .75 lbs/head/d) of PN for 30 d before the experimental period.

Experiment 5. Pine needles from Ponderosa pine trees contain biologically active components responsible for inducing abortion in cattle. We are employing solvent extraction methods for the purpose of fractionating active principles from inactive components of the pine needles. Extracts are evaluated by Dr. Ford for their abilities to reduce the flow of blood through the placentome perfusion assay system. Organic solvents including ether, chloroform, and methanol, remove waxy solids representing 26% of the weight of the needles. The most active extracts, representing about 2% of the total weight of pine needles, are further fractionated with a procedure known as chromatography.

Experiment 6. We have shown previously that the effect of the pine needles is to severely reduce blood flow to the uterus resulting in an induced parturition. Regulation of uterine arterial diameter, and consequently blood flow, is accomplished by a complex series of signals from the autonomic nervous system, cell receptors, membrane transport systems, and uterine estrogens. We do not understand how pine needles affect this system so this study was done to increase our understanding of the effect of pine needles on the control of uterine blood flow.

Eighteen pregnant cows were assigned to be controls, pine needle-fed for 3 days, or pine needle-fed for 5 days. The cows were bred at Fort Keogh so that they would be at the right stage of pregnancy and then were shipped to Iowa State for the actual experiment. Blood samples were collected during the experimental period, and then the cows were slaughtered in order to collect appropriate fetal, uterine, and maternal tissues. Placentomes were perfused to evaluate the effects of pine needles on blood flow, and specific tissues were analyzed for the enzyme peroxidase, which converts estrogens to catechol estrogens, and for adrenergic receptors (a_2).

Results

Experiment 1. Results of this experiment are summarized in Table 1. Feeding pine needles decreased (P < .01) the interval to parturition in both buffalo and cattle. In both species all calves were born alive, but all cows that were fed needles had retained placenta. No complications related to retained placenta were observed. One 3-yr-old buffalo had little milk and would not accept her calf, so the calf was bottle fed and sold. Two calves from the cattle fed pine needles died shortly after birth. Buffalo had a slightly longer interval to calving after pine needle feeding than did cattle (P < .05).

Table 1. Interval (d) to calving in buffalo and cattle as affected by feeding pine needles.

	Buffalo[a]			Cattle[b]		
Treatment	n	Days	Range	n	Days	Range
Control	6	23.0 " 5.2	16 to 28	11	32.6 " 4.2	24 to 39
Pine needle[b]	6	7.7 " 1.4	5.5 to 9	7	5.1 " 2.3	3 to 10

[a] Control vs pine needle within species (P < .01).
[b] Pine needle-fed, buffalo vs cattle (P < .05).

Experiment 2. Feeding PN free choice gave an intermediate response as compared to negative and positive controls (Table 2, P < .01). Neither protein level of the diet nor having a salt-sulfur block available affected the response to PN (P > .5).

Table 2. Effect of protein content of the diet and a salt-sulfur supplement on abortion response to pine needles.[a]

		PN in	PN fed free choice			
Item	Control	diet	AP	HP	AP-SS	HP-SS
No. of cows	11	7	10	10	10	10
% aborted	0	100	80	50	40	50
Interval[b]	32.6	5.1	16.8	21.0	20.2	19.8

[a] Treatments were: PN, pine needles; AP, adequate protein diet; HP, high protein diet; SS, salt-sulfur block available free choice.
[b] Interval from start of study (at 250 d of gestation) to calving.

Experiment 3. Cows that were fed a base diet of corn silage did not abort as compared to a high percentage of cows which aborted on a hay diet (Table 3, P < .01). Whether the diets were limit fed or free choice fed had no effect. PN consumption was not measured because the cows were group fed; however, no cows in the corn silage groups were observed eating needles, and no needles were removed from the bunks.

Table 3.Effect of a silage- or hay-based diet and limit feeding vs free choice feeding on abortion response to free choice feeding of pine needles.

	Treatment[a]				
Item	Control	PN-SDL	PN-SDAL	PN-HDL	PN-HDAL
No. cows	14	6	8	8	7
% aborted	0	0	0	75	71

[a] Treatments were: SD, corn silage diet; HD, alfalfa hay diet; L, diet limit fed; AL, diet free choice fed; PN-, pine needles fed free choice.
[b] Interval from start of study (at 250 d of gestation) to calving.

Experiment 4. Prefeeding PN at a low level decreased the effect of subsequent feeding at higher levels, but this effect was only to delay (Table 4, $P < .01$) the abortions and not to prevent them.

Table 4.Effect of prefeeding low levels of pine needles for 30 d on response to an abortifacient dose of pine needles.

	Treatment[a]			
Item	Control	PN	.1PF+PN	.3PF+PN
No. of cows	8	8	8	6
% aborted	0	100	75	83
Interval[b] (d)	34.6	5.5	10.7	16.4

[a] Treatments were: PN, pine needles fed at 2 kg/d; PF, prefed for 30 d at either .11 or .34 kg/d.
[b] Interval from start of study (at 250 d of gestation) to calving.

Experiment 5. A fraction which we designate as F7(1-10), representing only .05% of the total plant material, was highly vasoactive. The active fraction has been subjected to spectral analysis (mass spectrum, proton nuclear magnetic resonance spectrum, and carbon nuclear magnetic resonance spectrum), and chemical analysis in attempts to identify the chemical structure of the active principles in pine needle extracts. The structure of the active compound appears to be very complex. However, with a combination of chemical, spectral, and chromatographic analytical methods, we expect to have this new vasoactive compound from plants identified soon.

Experiment 6. Placentomes from pine needle-fed cows reacted much differently than placentomes from control cows in the perfusion system, and the tissue analysis revealed that peroxidase activity of uterine tissues from pine needle-fed cows was increased. Blood flow of the pine needle-fed cows apparently was decreased as observed in previous experiments; the uterus was trying to correct this effect by producing more catechol estrogen through elevations in peroxidase.

Discussion

Feeding corn silage as the base diet prevented cows from eating pine needles (Exp. 2). We do not know the basis for this effect, but it may involve amount of fill or other physical differences between the diets. Silage-based diets are probably not options to be considered by producers to minimize risks because silage is not readily available in most cases. None of the other variables in these studies or those reported earlier affected either response to PN or consumption of PN; therefore, feeding straw, mineral, bentonite, and(or) salt are not management options to decrease risk unless they can be used to draw cows away from pine trees.

Abortion rates with free choice PN feeding were lower in Experiments 1 and 2 when pen space was larger and cows were group fed as compared to abortion rates we have observed in earlier experiments where pen sizes were much smaller and cows were individually fed. Behavioral aspects such as boredom may play a role in susceptibility to PN consumption.

Cows prefed low levels of PN took longer to abort indicating that some compensatory effects were induced but not sufficient to completely block the response. Similar conclusions were drawn from the data from the cows killed after being fed pine needles. These observations are useful for understanding mechanisms and devising treatments. A better understanding of the mechanisms combined with identification work described in Experiment 4 will aid in our eventual goal of determining ways to prevent or cure this problem.

Recent Publications

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A New Concept in Palpation Chutes

W.E. Larsen and R.E. Short

Introduction

Restraining chutes for cattle and other livestock need to be built to fit the animal so that the animal will stand quietly and not fight to get free. A stall or chute that fits the animal closely will hold it safely in place and discourage climbing and jumping. The benefits are reduced animal stress, reduced handler frustration, improved performance, and most important, increased operator safety. A properly fitted chute will also reduce the chance that the animal will fall or get caught in the chute. Conventional squeeze chutes and head gates often exceed restraint requirements for many operations and cause the animal to fight to get free from the restraint.

A variable dimension chute that holds the animal gently in place is particularly important for pregnancy testing and other examinations conducted by rectal palpation. The animal needs to be positioned at the rear of the stall so that the operator can either stand outside the stall to perform the examination or easily and quickly step outside. Current palpation chutes provide gates to give the operator easy access, but the operator must still work between the narrow side walls of the chute while performing the examination. The position of the operator behind the animal places him in a hazardous and awkward position. Any system that causes the animal to hold still and provides additional working space for the operator will result in a safer and more convenient operation.

Variable Dimension Design

A variable dimension restraining chute for use as a palpation stall was developed to replace a conventional palpation stall at Fort Keogh. This design provides improved safety and operating ease for palpating cattle. The variable dimension palpation chute is shown in Figure 1. The design keeps the adjustable side panel vertical and allows the operator to adjust the width in infinite increments. The length is also adjustable to force the animal back against the leg bar at the back.

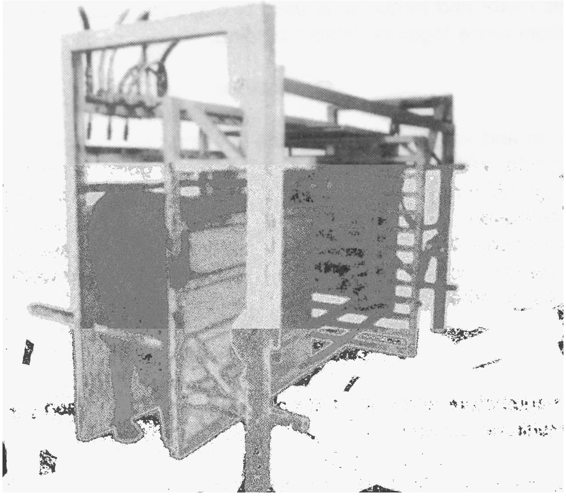

Figure 1. Variable restraining chute.

The animal is always held firmly at the back of the chute and there is no room for forward and backward or sideways motion.

Control Mechanisms

There are three primary mechanisms used to adjust the variable dimensions as needed for the palpation chute. These consist of the side panel width control, the gate closure control, and the stall length or gate position control. The mechanisms are operated by hydraulic power, which is ideal, as it places the control levers close to the operator and requires a minimum of effort. Electric power with linear actuators and gear head motors could also be used.

Side panel width control. Variable width is obtained by moving a vertical side panel in and out as needed. The side panel is supported on each corner by a hinged arm. These support arms are connected with a parallel linkage on each support post to guarantee that the panel moves uniformly through its entire range of motion. A torque tube connects the linkages from one support post to the next to force both ends of the moveable side panel to move smoothly and evenly over the entire range. The controls are located above the fixed side panel and can be operated from the working side of the stall.

Gate closure and gate position control. The gate at the front of the chute must be opened and closed to hold and release the animal. The gate is mounted on the swinging side panel so that it will not extend into the working area when opened. The gate slides through guides that allow it to move in and out as needed. Chains at the top and bottom of the gate operate around idler sprockets and a drive sprocket on a hydraulic motor to force the gate to open and close smoothly. A hydraulic valve senses the gate position and stops the hydraulic motor when the gate is closed to prevent damage to the gate or side panel. The valve also releases the gate if the swinging side panel is moved inward when the gate is already closed.

The length of the chute is adjusted by moving the gate forward with a drive mechanism similar to that used to open and close the gate. The gate slides in guides on the swinging side panel. Chains at the top and bottom of the gate force it to move smoothly. The same type of hydraulic motor and torque shaft used to close the gate is used to guarantee that the top and bottom move together without binding.

Conclusions

The variable width and length palpation chute is being used successfully at Fort Keogh. The palpation chute, which was sized for cattle, gives good control of animals during pregnancy testing, A.I., embryo transfer, and other procedures. The operators are pleased with its ease of operation. The operator's working position, safety, and ease of adjustment are major improvements from conventional palpation stalls. The success with cattle has shown that the same principle, with changes in dimensions, would work equally well with other livestock and in other types of livestock handling facilities.

License Agreement

The license to manufacture and market the palpation chute has been granted to Blue Sky Enterprises of Melstone, Montana.

Recent Publications

Larsen, W.E. and R.E. Short. 1993. Variable Dimension Livestock Restraining Cage. ASAE Applied Engineering in Agriculture (accepted).

Nutrition Research at Fort Keogh: A Historical Perspective

E.E. Grings

Introduction

The free-roaming animal provides a unique challenge to the researcher attempting to assess plant-animal interactions. Diet diversity, large grazing areas, nutrient costs associated with grazing, and environmental stresses all interact to influence nutrient intake and utilization as well as requirements. Nutritionists working with grazing animals have had to develop unique techniques to assess diet quality and intake under extensive conditions. Researchers at Fort Keogh have taken advantage of the laboratory's unique resources to study the nutrition of cattle under extensive management conditions. This has involved development of new techniques and validation of routine techniques for use under conditions in the Northern Great Plains. Despite the difficulties in this type of research, scientists at Fort Keogh have gained recognition for their evaluation of the nutritional status of grazing cattle. Much of the work has focused on protein and energy supplementation of grazing cattle as well as environmental factors affecting grazing behavior and intake and nutritional factors affecting reproduction of beef cows.

The range cattle nutrition program at Fort Keogh formally began in 1971. However, research into the nutrition of beef cattle and other species of livestock and poultry has taken place at Fort Keogh since its inception as a research station in 1924. Research into nutritional factors involved in optimal production of livestock under Northern Great Plains range conditions, the role of nutrition in regulation of physiological mechanisms, and nutritional factors affecting expression of genetic traits have been important components of Fort Keogh's research program since the 1920's.

Early Studies (1924 - 1970)

Initial nutrition studies included sheep, swine, horses, and turkeys in addition to beef cattle. Many studies were initiated in the 1920's to evaluate local feedstuffs for livestock and poultry production. This included evaluation of alfalfa hay, corn silage, wheatgrass hay, barley, and wheat mill screenings.

Sheep studies included testing the value of feeding grain to ewes on winter range. Corn and cottonseed cake were compared for supplemental winter feeding, and evaluations were made on bone meal for ewe lambs and corn silage and wheat mill screenings as feed sources for fattening lambs.

Corn and barley for swine were first compared in feeding trials on the station in 1925. These studies were conducted with pigs pastured on dry land alfalfa. The effect of these two grain sources on subsequent gains in the feedlot was also evaluated. Studies on the relative value of corn and barley diets for swine continued into the 1980's until the swine research program was moved from Fort Keogh to Bozeman. Other feedstuffs for hogs were tested, including tankage, wheat, safflower meal, and linseed meal.

Little horse nutrition work was conducted at Fort Keogh. However, range forage for growth and maintenance of working horses was examined during the 1920's. In 1926, feed and work records of 46 horses and mules were kept for evaluating the feed cost per horse per day of labor. At that time it required 48**4** per horse work day. Horses averaged 137 days of work per year.

Turkey studies conducted from 1929 to 1939 included developing rations for maximum growth with low mortality. Fort Keogh was one of the first research stations to publish information on improving the hatchability of turkey eggs. Some of this information was nutritional in nature and was readily adapted by turkey growers and feed companies.

Early nutrition work involving beef cattle included evaluating combinations of alfalfa hay, corn silage, and cottonseed cake for wintering calves; comparing alfalfa and western wheatgrass hays for replacement heifers; and testing the value of supplying protein (cottonseed cake) to beef cows wintering on range.

Beef Cattle Research

Environmental effects on nutritional demands. The struggle with environment and its effect on nutritional demands has always been a topic of interest in the Northern Great Plains. Studies on winter supplementation have shown variable response that is related to the severity of weather conditions. Studies were conducted during the 1970 and 80's on the effect of environment on intake and grazing behavior of cattle. Grazing time, forage intake, and digestibility have been found to be reduced as average daily temperature decreases. This, coupled with an increased energy demand for maintenance, can have profound effects on weight gain and body composition of wintering cows and their response to supplementation.

Protein and energy supplementation. The value of protein for wintering beef cows has been a recurring theme in the nutrition research at Fort Keogh, beginning in 1929 and continuing through today. In the winters of 1929 through 1934, protein supplementation for Hereford cows wintered on range was evaluated. Response to protein supplementation depended upon the previous summer's rainfall and the amount of snow cover. In years of good forage with little snow cover, protein supplementation was of no economic benefit although supplemented cows came through the winter in better body condition. In years of poor forage because of summer drought or when heavy snow cover was present, most cows fed cottonseed cake survived the winter on the range while nonsupplemented cows had to be moved to the drylot and fed hay. A similar situation was observed in the mid-1970's when response to winter protein supplement was dependent upon forage quality and availability. Forage intake and digestibility were not affected by either protein or grain supplementation during the first, relatively mild winter. However, during the second winter with heavy snow and extended periods of cold weather, forage intake was increased by feeding soybean meal at a rate of 1.5 lbs/d every 2 to 3 days. Total dry matter digestibility was also increased by feeding protein. Cows fed cracked barley during this period had similar forage intake and total dry matter digestibility to those not fed any supplement but forage digestibility was depressed by grain feeding. Body weight and condition score changes were not affected by either supplement.

A 26% protein soybean meal-barley pellet (1.75 lbs/d) was fed to ruminally cannulated steers with or without a monensin ruminal delivery device to evaluate the effects on intake and digestive function during the winter. Protein supplementation increased ruminal ammonia concentrations and organic matter digestibility while decreasing gastrointestinal tract fill and particulate passage rate. Cattle having a monensin delivery device and receiving additional protein had an even greater particulate passage rate. Forage intake was not affected by either protein or monensin.

The increase in forage digestibility is a means to provide added nutrients to cattle grazing winter range.

Studies on the timing, type, and amount of protein have been conducted to more firmly define the conditions under which protein supplementation is most profitable. Alfalfa cubes or cottonseed meal-barley pellets were fed on an equal protein basis and evaluated as a fall/winter protein supplement for pregnant cows. Supplemented cows gained weight and gained or maintained body condition while unsupplemented cows lost weight and condition. Performance among cows fed the 2 supplements was similar.

Supply of specific amino acids may be a means of meeting protein requirements of cattle. The feeding of methionine hydroxy analog (MHA) to beef cows was tested in the early 1970's. Cows fed this amino acid analog at a rate of 15 g/head/d from 30 d before until 60 d after calving produced 1.8 lbs/d more milk with .8% more butterfat than cows not receiving MHA. This translated into increased average daily gain and weaning weight of calves from dams receiving the MHA at 15 g/head/d. Cows receiving 5 g/head/d were intermediate in milk production and butterfat content.

Other studies have shown that while protein supplementation during the winter may improve intake and digestibility of range forage, grain (energy) supplements may lower intake of forage. One study showed that the negative effects that energy supplementation may have on changes in weight and body condition can be lessened by feeding grain on a daily rather than on an alternate day basis.

Level of forage intake was found to affect many ruminal characteristics such as Ph and ammonia concentrations. Liquid dilution rates increased linearly and liquid volume decreased as forage intake increased from 1.4 to 2.4% of body weight. Diet quality and ruminal characteristics of yearling steers were followed throughout 1 growing season. As the season advanced, ruminal ammonia concentrations and fluid dilution rates decreased whereas fluid volume and liquid turnover increased. Volatile fatty acid patterns were more favorable for steer weight gain early in the season. These patterns suggest that protein supplements or buffers may be useful late in the growing season to improve forage digestibility.

A study in which monensin and/or rolled barley were evaluated for their effect on digestive kinetics of steers grazing summer range showed that ruminal propionate concentrations could be increased by either of these means. This could be favorable to weight gain in growing cattle grazing summer range. A study with steers grazing fall pasture showed that the time of day at which an energy supplement was fed had important effects on nutrient intake. Steers fed in the morning (7:30 a.m.) ate less feed and had a lower digestible energy intake than steers fed in the afternoon (1:30 p.m.). This difference was related to the interruption of normal grazing behavior.

A study was conducted to evaluate diets for early weaned calves. Calves were weaned at about 84 days of age and fed free-choice alfalfa hay with either whole barley, rolled barley, or whole oats fed free-choice. The results showed that calves fed barley gained weight at a faster rate (2.1 lbs/d) than those fed oats (1.8 lbs/d). Rolling the barley did not show any real advantage over feeding whole barley (2.2 vs 2.0 lbs/d, respectively) for calves of this age. This study did show that calves that must be weaned from their dams can be raised on commonly available feedstuffs with a minimum input of resources.

Mineral nutrition. Interest in the mineral nutrition of cattle first came to light at Fort Keogh during the dry summer of 1934 when cattle were observed to consume over twice as much salt as in the more normal rainfall year of 1933. Subsequent studies showed that annual salt consumption was positively correlated with total May and June precipitation. It was hypothesized that this could be due to leaching of minerals from forages during heavy rainfall. Salt consumption was found to be greatest in August, September, and October. Results showed also that salt consumption was not influenced by stocking rate.

During the late 1940's and early 1950's, grazing studies were being conducted at the Hogback/Lone Pine units, and additional information was gathered on the mineral and vitamin status of the cattle grazing those pastures. Calcium, magnesium, and phosphorus concentrations of the range forage where measured throughout the year and blood samples collected to evaluate mineral status of the cattle grazing the area. In the summary of that study, published in 1959, it was stated:

> *"that, in general, it may be expected that breeding cattle can be run on the range in the Northern Great Plains without protein, vitamin, or mineral supplements with satisfactory productive performance and without developing nutritional deficiencies; provided that the range is not overstocked, and realizing that there may be areas within the plains region in which nutritional deficiencies may occur."*

Several changes have occurred since the 1950's that have caused us to reevaluate our previous statements regarding protein and mineral supplementation. First, livestock of the 1950's differ genetically from what we raise today. Cattle have been selected for improved performance and there has been an influx of a variety of breeds into commercial cattle operations in the Northern Great Plains. This may have resulted in larger cattle with different nutritional demands. Many pioneering statements regarding nutritional needs may not suit today's cow. Secondly, our understanding of mineral needs has gone far beyond the macroelements. In recent years, a greater emphasis has been placed on the trace element requirements of livestock. We are currently attempting to evaluate these needs in light of current production practices.

Nutrition research techniques for the free-ranging animal. Research into nutritional techniques at Fort Keogh has focused on developing and evaluating research techniques for the grazing animal. During the 1980's, several unique techniques were evaluated. An automated data acquisition system was developed to collect frequent animal weights and water intake measurements without altering behavior of grazing livestock. This has facilitated our studies examining the dynamics of body weight changes in grazing cattle. Surgical techniques for esophageal cannulation of suckling calves and for attachment of esophageal bags to older animals were developed and are routinely in use today. Using these techniques, we have shown that suckling calves select a diet higher in protein and lower in fiber than mature steers through much of the summer. Such findings emphasize the importance of using cannulated cattle similar in age to other experimental animals used in nutrition studies.

Techniques to measure intake, digestibility, and rates of passage were also evaluated throughout this period. Adoption of the most promising techniques has improved the intensity and accuracy of the data we collect today on the role of nutrition in efficiency of production. We have been using a sustained release chromic oxide bolus for much of the recent intake work. The use of this bolus was validated in steers and calves. It was found, however, that some animals must be fitted with fecal bags to obtain a correction factor for the bolus release rate.

The role of nutrition in reproduction. A great deal of research has been conducted at Fort Keogh on the effect of nutrition on physiological processes. The effects of energy and protein at various stages of the life cycle have been tested for their effect on pregnancy rates, calving difficulty, and onset of puberty. Studies have ranged from measurement of fall pregnancy rates related to feeding levels before and/or after calving to very detailed studies on the influence of nutrients on the very complex hormonal mechanisms affecting reproduction.

Two studies were conducted to evaluate reproduction in cows grazing seeded pastures compared to native rangeland during the prebreeding and breeding period. In the first study, pastures seeded to either crested wheatgrass-alfalfa or russian wildrye-alfalfa were compared to native range for early spring grazing. Calf crop weaned averaged 8-10 percentage points lower for cows on native range. In the second study, pastures that were evaluated included native range, pastures that had been seeded to crested wheatgrass or russian wildrye, and a pasture that had been contour furrowed and seeded with alfalfa. Grazing began on these pastures from mid-April to the first of May. Reproductive performance, as measured by calving date, time to first estrus, and fall pregnancy rate, was not affected by the use of seeded pastures. Eighty-five percent of the cows were observed in estrus before the breeding season, and fall pregnancy rates were 92.4%. It was concluded from the second study that properly managed native range was adequate for good reproductive performance.

Nutritional studies in support of research on pine needle abortion have included determining the effects of pine needle consumption on digestibility of grass hay. Digestibility of organic matter, protein, and fiber all decreased with increasing amounts of pine needles in the diet. This suggests that pine needle consumption may be detrimental to the overall nutritional status of cattle as well as having abortifacient effects.

Nutrition and genetics. To set standards for bull testing in the 1930 and 1940's, studies were conducted on appropriate rations and the length of the feeding period needed to evaluate sires. A discussion was presented in a 1941 Experiment Station Bulletin on the possibility of the effect of both utilization of nutrients (feed efficiency) and/or food intake capacity on differences in growth rate among progeny. An interaction between genetics and nutrition was reported in a 1943 Experiment Station Bulletin when the susceptibility of cattle to bloat was shown to be partially genetic.

The Future

As we look toward rangeland agriculture in the 21st century, scientists at Fort Keogh continue to contribute to nutritional research through integrated projects at the laboratory and through involvement in cooperative studies with Montana State University and other research institutes. We continue to pursue many of the same problems that were plaguing livestock producers in the 1920's: the value of protein supplementation for wintering cows, the mineral needs of grazing livestock, and the value of local feedstuffs for use in rangeland-based cattle operations. We have made improvements in the efficiency of production over the last 68 years, but we have not found solutions to all our problems. As we continue to make genetic and reproductive progress, the nutritional status of our cattle needs evaluation to ensure that we are providing the nutrients required to meet their optimal potential in their environment.

Range Cattle Nutritionists at Fort Keogh

Individual	Years at Fort Keogh	Position
L.W. Varner	1971 - 1974	Research Animal Scientist
R.J. Kartchner	1974 - 1983	Research Animal Scientist
D.C. Adams	1981 - 1990	Research Animal Scientist
E.E. Grings	1991 - present	Research Animal Scientist
Current Nutrition Research Support Staff		
B. Hould	1991 - present	Research Associate
R. Bonine	1988 - present	Farm/Ranch Hand
J. Gresens	1976 - present	Biological Lab Technician
B.L. Balsam	1990 - present	Biological Lab Technician
M.S. Reil	1992 - present	Biological Lab Technician

Protein Supplementation for Stocker Cattle in the Northern Great Plains

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

Introduction

Past research has shown that range forage in eastern Montana may become deficient in protein for growing cattle during late summer. Unsupplemented steers grazing native range in late August and early September have been shown to cease gaining or even to lose weight. A 2-year study was conducted to determine if providing a protein supplement throughout the summer months would affect weight gains of growing cattle grazing native range.

Materials and Methods

Experiments were conducted in a single 435 acre pasture of native range at Fort Keogh LARRL. Dominant forages were western wheatgrass, Japanese brome, blue grama, and needle-and-thread. Annual precipitation was 5.3" in 1988 and 15.1" in 1989 compared to a 92-year average of 13.3" .

In the first study (1988), the pasture was stocked with twenty-four 13-month-old steers (spring steers), eleven 7-month-old fall steers, and 13 fall heifers. A protein supplement (28.8% crude protein, CP) was provided to 13 spring steers and 12 fall calves at rates of 2.8 and 3.6 lbs of supplement every other day, respectively. This level of supplementation was expected to meet the needs of cattle gaining about 1.75 to 2.2 lbs/d, assuming a daily dry matter (DM) intake of 2% of body weight of a forage containing 6 to 6.5% CP. In study 2 (1989), the same pasture was stocked with 24 spring steers (12 control, 12 supplemented), 24 fall steers (12 control, 12 supplemented) and 11 fall heifers (6 control, 5 supplemented). Spring steers were fed 2.2 lbs and fall calves 4.0 lbs of the supplement every other day. Twice during each experiment, forage intakes were estimated for steers. Diet quality was evaluated using esophageally cannulated steers. Experiment 1 was terminated after 60 days due to low forage availability associated with low precipitation. Experiment 2 was conducted over an 80-day period.

Results

Diet quality. In experiment 1, dietary protein on June 21 averaged 7.3% whereas on August 21 it averaged 5.6% (dry matter basis). Limited precipitation during the year apparently reduced both quality and quantity of forage. In experiment 2, dietary protein on August 1 averaged 8.0%, whereas on September 14 it averaged 8.3%. Based on estimated intakes, approximately 80% of the CP requirement of steers was met through forage consumption. Addition of a protein supplement increased CP intake to 85% of requirement in experiment 1 and 98% of requirement for experiment 2.

Intake and digestibility. Neither forage organic matter (OM) intake (% of body weight) nor forage OM digestibility was affected by supplementation in either experiment. The addition of supplement did increase total OM intake (forage + supplement) in June of 1988 (Table 1), but not at any other time that intakes were measured. Intake and digestibility were affected by the age of the steers and the dates of sampling. Fall steers consumed more feed per unit of body weight and had lower forage digestibility than spring steers. The average forage OM intake for the 2 years was 1.6% of body weight for the spring steers compared with 2.0% of body weight for the fall steers. Average OM digestibility was 62.2% for spring steers and 61.2% for fall steers. Intakes for both animal ages were greater and digestibility less at the latter sampling date each year.

Table 1. Least squares means for total organic matter (OM) intake (% body weight) of steers in experiment 1.

	Spring-born				Fall-born				
	Control		Supplemented		Control		Supplemented		
Item	Jun[a]	Aug	Jun	Aug	Jun	Aug	Jun	Aug	SEM
No. of animals	5		5		5		5		
Total OM intake[bcde]	1.4*	1.9	1.8*	2.0	1.7*	2.3	2.0*	2.4	.05

[a] Dates for intake trials were 20 - 24 Jun. and 15 - 19 Aug. for experiment 1.
[b] There was a significant effect of date in the model (P < 0.01).
[c] There was a significant effect of type in the model (P < 0.05).
[d] There was a tendency toward an effect of supplementation (P = 0.06).
[e] There was a tendency toward a date x supplementation interaction (P = 0.08).
* Means comparing control and supplemented cattle within type and date differ at P < 0.05.

Animal performance. Average daily gains were increased by protein supplementation in the first experiment (Table 2). Final weights were greater in supplemented fall steers than in nonsupplemented fall steers. Final weights of steers and fall heifers were not affected by protein supplementation.

Table 2. Least squares means for weight and average daily gains of steers and heifers in 2 years.

	Spring Steers		Fall Steers		Fall Steers		
Item	Control	Supplemented	Control	Supplemented	Control	Supplemented	SEM
Experiment 1							
No. of animals	11	13	5	6	7	6	
Weight, lb							
Initial[a]	736	720	452	498	474	466	7
Final[abd]	828	827	522[e]	610[f]	575	570	7
ADG, lbs/day[c]	1.4	1.8	2.2	1.7	1.6	1.6	0.04
Experiment 2							
No. of animals	12	12	12	12	6	5	
Weight, lb							
Initial[a]	844	857	405	403	407	401	7
Final[ac]	930	974	531	573	520	553	7
ADG, lbs/day[ac]	1.1	1.4	1.6	2.1	1.4	1.9	0.04

[a] There was an effect of animal type ($P < 0.01$).
[b] There was a type X diet interaction ($P < 0.05$).
[cd] There was an effect of diet at ($P < 0.01$) or ($P < .05$), respectively.
[ef] Means within animal type with different superscripts differ ($P < 0.01$).

In experiment 2, average daily gains were again increased by protein supplementation. Average daily gain was also greater for fall-born cattle than spring-born. Spring and fall steers receiving supplement were 40 and 44 pounds heavier, respectively, and fall heifers 33 pounds heavier at the end of the grazing period than their nonsupplemented counterparts.

Conclusions

Protein supplementation was beneficial to growing cattle grazing Northern Great Plains rangelands in late summer and fall. The decision to supplement should be made based upon expected response coupled with economic and management considerations such as: the price of supplement in relation to the price of cattle, the cost of labor to provide supplement, and whether there is any advantage to stimulating compensatory growth after the summer grazing period.

Recent Publications

Grings, E.E. and R.E. Short. 1992. Nutritional aspects of lean beef production, p. 6.1-6.10. In Proc. 43rd Montana Livestock Nutrition Conference. Montana State Univ., Bozeman.

Mineral Dynamics of Forage Grasses in the Northern Great Plains

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

Introduction

When range vegetation has been analyzed for mineral content, potential deficiencies for livestock are often noted. Moreover, tissue class (live vs dead) has been found to be a major factor affecting nutrient concentrations in grasses. Variations in herbage nutritive value may be related as much to changes in the proportions of live and dead material as to changes associated with phenological development in plants. The objective of this study was to evaluate spatial and temporal variations in mineral concentrations of major forage species in the Northern Great Plains in relation to their ability to meet the nutrient needs of grazing livestock.

Materials and Methods

Plots were located on 2 soils common to Custer County: Sonnet silty clay and Eapa loam. Sampling dates were July, August, and September 1991, and April, June, July, August, and September 1992. Plants were harvested by species or species group. Herbage samples were dried and weighed. Live and dead materials were separated and weighed to obtain live/dead ratios. Samples were then ground for chemical analysis. Chemical analysis included concentrations of calcium, phosphorus, magnesium, potassium, sodium, manganese, zinc, and copper. Results reported herein are for western wheatgrass (WWG), other cool-season perennial grasses (primarily Sandberg bluegrass and needle-and-thread) (CSG), and warm-season shortgrasses (blue grama and buffalograss) (WSG).

Results

WWG was the only species found on all sites, and mineral analyses of WWG revealed that soil type affected concentrations of magnesium, potassium, sodium, and manganese (Table 1).

Table 1. Effect of soil on mineral concentrations of western wheatgrass.

	Sonnet silty clay	Eapa loam
Calcium, %	.23	.24
Phosphorus, %	.12	.11
Magnesium, %	.11*	.08
Potassium, %	.96*	.84
Sodium, %	.005*	.003
Zinc, ppm	17.0	17.0
Copper, ppm	3.0	2.0
Manganese, ppm	57.0*	38.0

*Average forage mineral concentration different for each soil type.

Calcium concentrations in WWG and CSG varied by date and tissue class. Calcium concentrations were somewhat erratic and fell below livestock requirements (Table 2) during a number of months. Calcium concentrations in WSG were not directly influenced by date or tissue class, and concentrations were always within the range required by livestock.

Table 2. Suggested ranges for mineral levels in diets of beef cattle and sheep (NRC, 1984, 1985).

	Beef Cattle	Sheep
Calcium[a], %	.27 - .48	.32 - .39
Phosphorus[a], %	.22 - .31	.26 - .29
Magnesium, %	.05 - .25	.12 - .18
Potassium, %	.50 - .70	.50 - .80
Sodium, %	.06 - .10	.09 - .18
Zinc, ppm	20 - 40	20 - 33
Copper, ppm	4 - 10	7 - 11
Manganese, ppm	20 - 50	20 - 40

[a]Range in requirement listed is for lactating cows or ewes.

Phosphorus concentrations in the live tissue of all plants declined with age and were adequate for lactating cows and ewes only in late April (Fig. 1). Concentrations of phosphorus in dead tissue were consistently well below animal requirements.

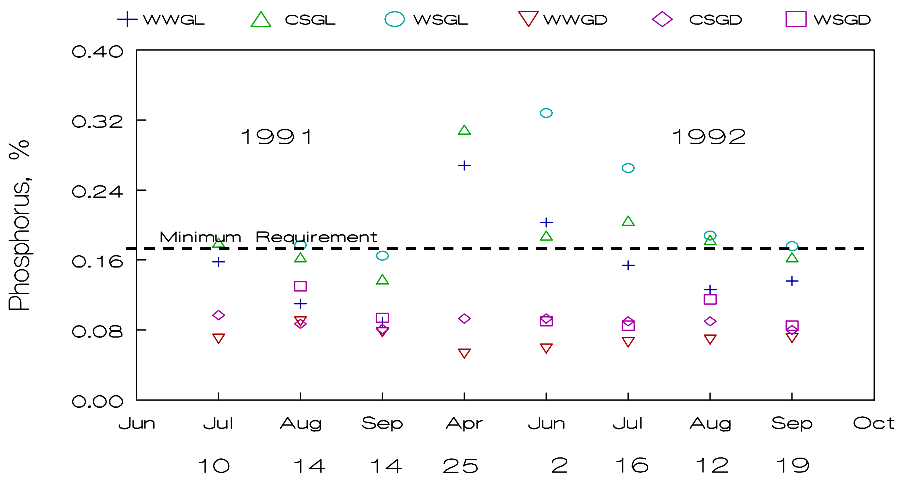

Figure 1. Phosphorus concentration of grasses. WWGL = western wheatgrass, live; CSGL = other perennial cool-season grasses, live; WSGL = warm-season short grasses, live; WWGD = western wheatgrass, dead; CSGD = other cool-season grasses, dead; WSGD = warm-season short grasses, dead.

The extent to which magnesium concentrations in WWG differed due to tissue class was affected by date. Although concentrations of magnesium met the minimum requirements for beef cattle, levels were below that required by beef cows in early lactation for the prevention of grass tetany (.20 %). Magnesium concentrations in WSG were affected by tissue class but not date. Concentrations in the live tissue were marginally adequate; whereas concentrations in the dead tissue were always deficient for sheep.

Potassium concentrations varied by tissue class over time for all forages. Potassium concentrations for live tissue were always within ranges considered adequate for cattle and sheep while concentrations in dead tissue were usually below required levels.

Sodium concentrations differed by tissue class over time for WWG but only over time for CSG. Sodium concentrations of WSG were not affected by date or tissue class. Sodium concentrations were always well below animal requirements.

Zinc concentrations in WWG rarely reached recommended levels for livestock (Fig. 2). Zinc concentrations in WSG were, at times, nutritionally adequate. Variability at a given sampling time was quite high for all grasses. With the exception of April 1992, mean zinc concentrations in CSG were below that required by livestock; however, variability was quite high.

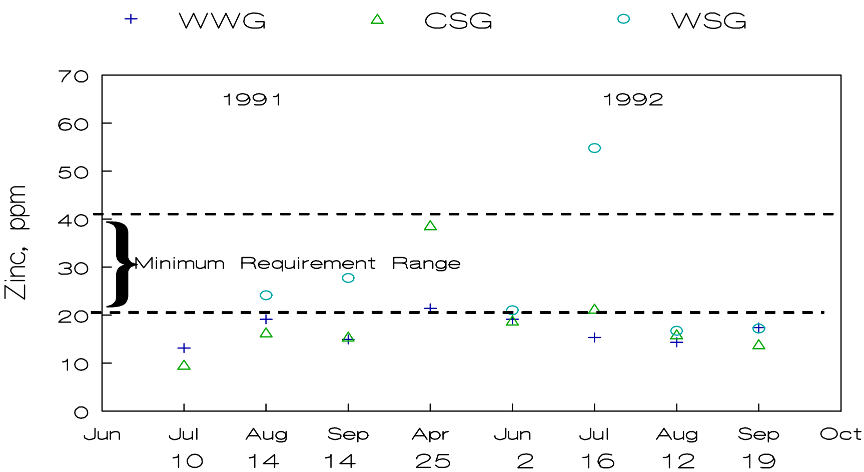

Figure 2. Zinc concentrations of grasses. WWG = western wheatgrass; CSG = other cool-season grasses; WSG = warm-season grasses.

Copper was not analyzed in samples collected in August or September 1991. Copper concentrations in WWG were affected by date (Fig. 3). Copper concentrations were adequate for cattle only in April 1992, and were never found in concentrations considered adequate for sheep. Copper concentrations in CSG did not vary with either date or tissue class. Concentrations of copper in CSG were inadequate for cattle and sheep in July 1991 and September 1992. WSG were not analyzed for copper concentrations in 1991 or in April 1992. Concentrations of copper in WSG were affected by date and were inadequate for cattle and sheep in August and September.

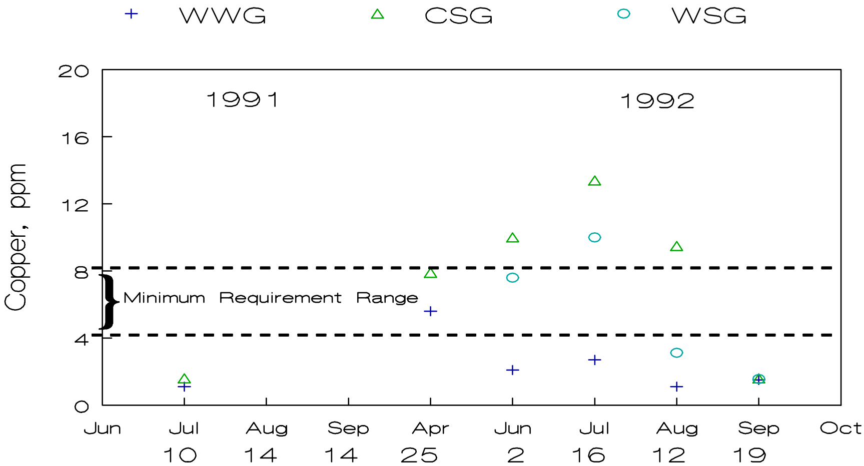

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Figure 3. Copper concentrations of grasses. WWG = western wheatgrass; CSG = other cool-season grasses; WSG = warm-season grasses.

Manganese concentrations in WWG varied in time by tissue class. Concentrations in live tissue were less than concentrations in dead tissue in June 1992, although variability at all times was fairly high. Both live and dead tissue had manganese concentrations within the range adequate for both sheep and cattle. Mean manganese concentrations of CSG and WSG were within required ranges; however, large variabilities in forage concentrations showed that some forage samples had concentrations of inadequate levels for livestock.

Conclusions

Concentrations of many minerals vary widely over time, among forages, and between tissue classes. Nutrient densities are often below recommended levels for grazing livestock. In this region, the minerals most likely to be found in concentrations considered to be deficient for livestock were phosphorus, zinc, copper, and sodium. Tissue class had a very pronounced effect on potassium and phosphorus concentrations, with dead tissue never containing concentrations of these elements in levels adequate for grazing livestock. Thus, the availability of live tissue in a forage mix can play a major role in the ability of the grazing animal to meet its nutritional demands.

Effects of Genotype and Management System on Postweaning Production Efficiency and Composition of Beef

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

Introduction

Efficiency (economic, biological, and/or energetic) of a beef production system is primarily affected by the quantity, density, and cost of nutrients consumed in relationship to the quantity and quality of meat produced. Sustainability of the production system will be enhanced by increasing the portion of nutrients derived from range forage (low cultural energy inputs) in relation to the portion of nutrients derived from cereal crops (high cultural energy inputs). Young, fast-growing animals are more efficient because of the lower portion of nutrient intake being necessary for maintenance. Beef production systems that include periods where range forage is utilized after weaning may have decreased biological efficiency associated with lower rates of gain, but sustainability and economic efficiency may be enhanced. Efficiency can also be affected by the genotype of the animal through its inherent potential for rate and composition of gain. A large, fast-growing animal may be at a disadvantage under range forage-based systems because the animal may be too large at slaughter for current industry standards, and its genetic potential for gain cannot be fully exploited. However, these animals may have an advantage whenever reasonable rates of gain can be attained, especially when composition of gain is taken into account (longer periods where gain is primarily protein as opposed to fat).

Methods

This experiment was conducted to determine the effects that genotype (high vs moderate growth rate potential) and management system (direct finishing, DF vs growing-finishing, GF) have on production efficiency after weaning. Crossbred cows (various crosses of Red Angus, Angus, Tarentaise, Charolais, and Hereford) were bred to either high yearling weight index Charolais bulls or to average index Hereford bulls. Male calves from these matings were born in April, castrated shortly after birth and weaned in late September. After weaning, half of the steers were put directly on a finishing ration (DF) and half were put on a growing ration (G) during the winter, grazed on range forage during the summer (diet estimated to be 2.25 Mcal ME/kg), and put on a finishing ration (GF) in late September. Rations on a dry matter (DM) basis included corn silage (CS), grass hay (H), barley (B), and a soybean meal-mineral supplement (S): DF = 40.0% CS, 56.2% B & 3.8% S, 2.79 Mcal ME/kg; G = 56.7% CS, 39.3% H & 4.0% S, 2.31 Mcal ME/kg; GF = 19.3% CS, 77.9% B & 2.8% S, 2.88 Mcal ME/kg. Individual animal nutrient intake was estimated (7 steers of each sire) using chromic oxide marker techniques while on pasture and a Calan-Broadbent system during the growing and finishing periods. Steers were slaughtered at the beginning and at 3 equally spaced times during the finishing period (DF at 0, 90, 180, and 270 d; GF at 0, 45, 90, and 135 d on feed). Carcass and body composition data were collected after slaughter. There were 4 Charolais- and 4 Hereford-sired steers slaughtered at each time period, and the experiment was repeated a second year (total n=128).

Results

For live weight, (Fig. 1) carcass weight (Fig. 2), and edible fat-free organic matter (FFOM, an estimate of protein) (Fig. 3), yearlings were heavier than calves (P < .01), Charolais-sired progeny were heavier than Hereford-sired (P < .01) but growth through the finishing period was not uniform with sire (G and SxG, P < .01). Hereford-sired progeny had proportionally less weight and FFOM at the last slaughter time than at earlier times indicating the earlier maturity of the Hereford breed. Differences were also observed in body fat (Fig. 4) and carcass grade, but the effects were not large. Hereford-sired steers were fatter compared to Charolais, and yearlings were fatter than calves (P<.01). Slaughter times were selected so that group 4 steers were anticipated to be at low choice (grade = 12). Only the Charolais-sired calves had not reached that average (11.6, average to high select). Daily gains were greater (Fig. 5) for yearlings than for calves and for Charolais- than for Hereford-sired steers (P < .01). Efficiency (Fig. 6) was greater in yearlings as compared to calves (P < .01) presumably because of the higher rate of gain in the yearlings. Efficiency decreased as time on feed increased (G, P < .01).

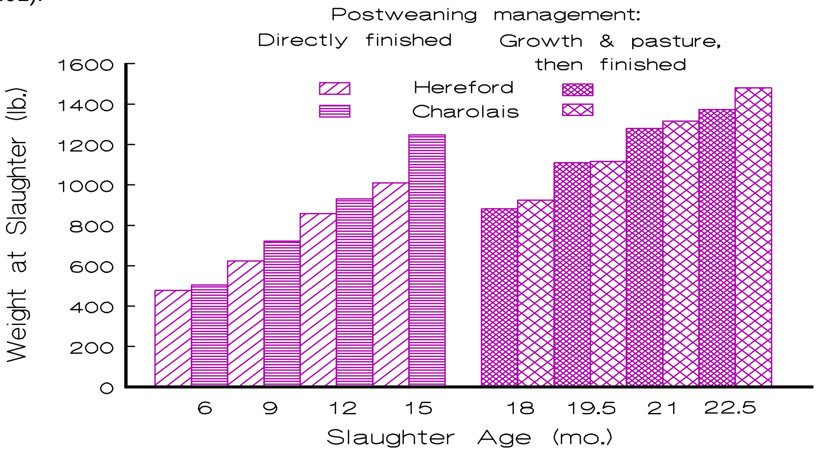

Figure 1. Slaughter weight.

Figure 2. Carcass weight.

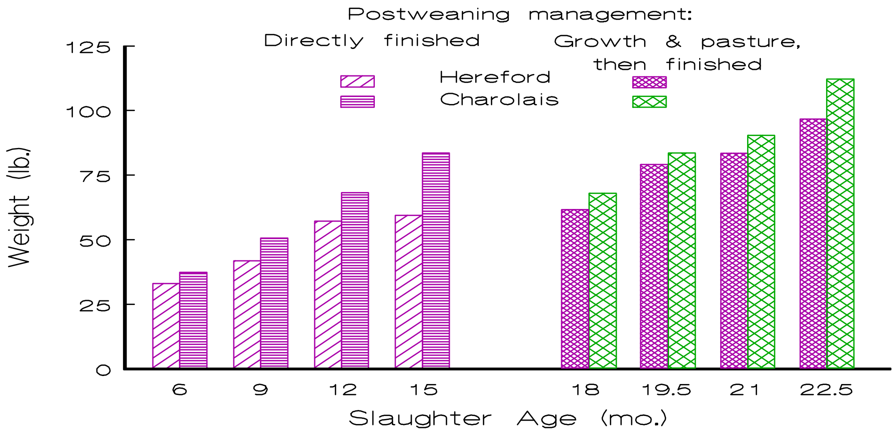

Figure 3. Fat free organic matter weight.

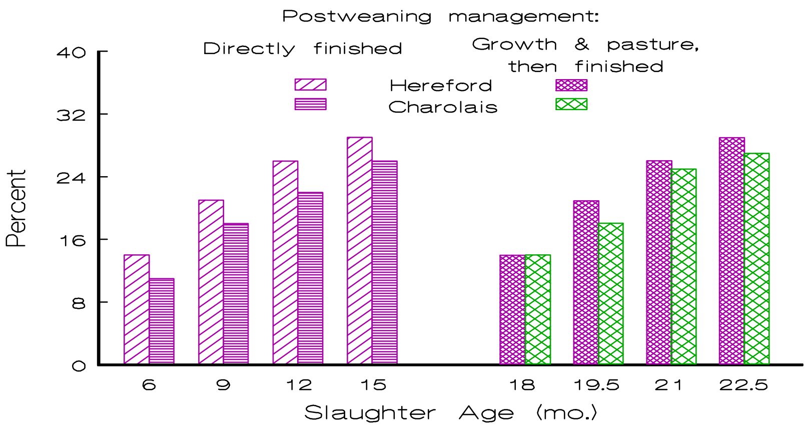

Figure 4. Percent body fat.

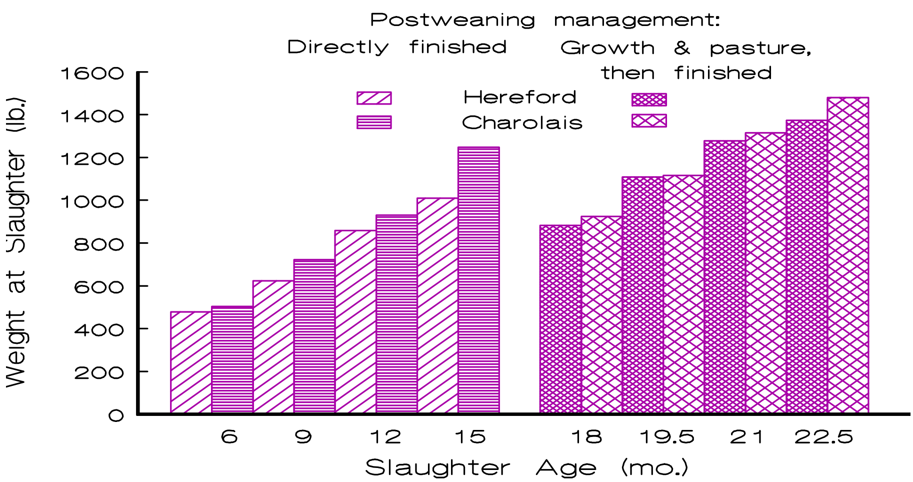

Figure 5. Daily weight gain.

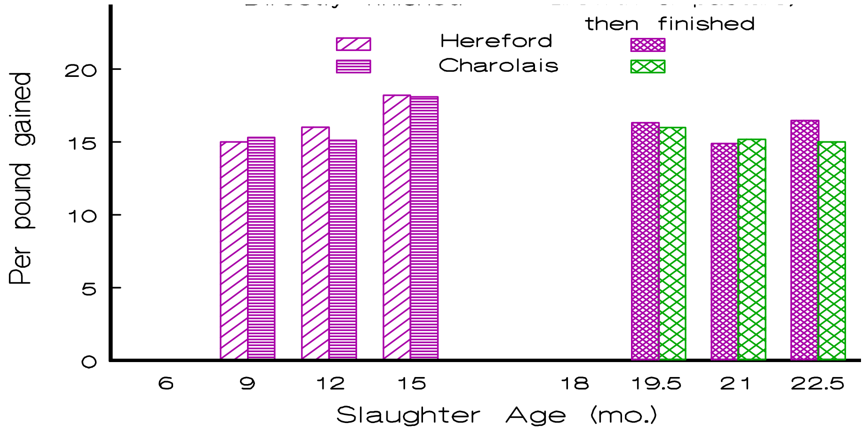

Figure 6. Megacalories of metabolizable energy.

Yearling steers were fed a growing ration during the winter after weaning and before going on pasture. Gain and efficiency during these periods are shown in Table 1. The only effect on gain and efficiency was that pasture gain was greater (P < .05) in Charolais-sired steers.

Table 1. Effect of sire on gain and efficiency during the growing and pasture periods.

Period:	Growing		Pasture	
Variable Sire:	H	C	H	C
Gain (lbs/d)	1.69	1.69	1.14	1.34
Mcal ME/kg gain	147	152	106	79

Conclusions

We conclude that steers with a high potential for growth gained faster and more consistently throughout the finishing period, produced more meat either as carcass weight or edible FFOM, were leaner, produced comparable grades of carcasses, and were comparable in efficiency. However, the high growth potential steers had very large carcasses by the time they reached choice grade when finished as yearlings. Steers that were grown out and then finished as yearlings gained faster, produced more meat as carcass weight and as edible FFOM, were fatter with higher carcass grades, and were more efficient. Total postweaning efficiency of the GF system is difficult to assess because the efficiency during the growing period was much less, growth during the pasture phase was obtained with no harvested nutrients, and total product produced was much larger.

Recent Publications

Adams, D.C., R.E. Short, M.M. Borman, and M.D. MacNeil. 1991. Estimation of fecal output with an intra-ruminal continuous release marker device. J. Range Manage. 44:204-207.

Adams, D.C., R.E. Short, J.A. Pfister, K.R. Peterson, and D.B. Hudson. 1991. Surgical establishment of esophageal fistulae in suckling calves. J. Range Manage. 44:628-629.

Effects of Sire Breed and Management on Cholesterol and Fatty Acids in Longissimus Muscle of Beef Cattle

D. Rule, R. Field, B. Ruan, and R.E. Short

Introduction

It is important to generate scientific data on cholesterol and fatty acid composition of beef because of real or perceived relationships to human health. Numerous studies have been conducted to determine the fatty acid composition as well as the cholesterol content of bovine tissues. Several studies have attempted to determine effects of breed and diet on fatty acids or cholesterol; however, consideration of breed x diet x maturity has not been attempted. The objective of this study is to ascertain how diverse beef cattle production systems affect the composition of meat; particularly the lipid composition which is important because of the concern by health experts of the effects that consumption of animal fats has on cardiovascular disease.

Methods

All cattle were born and reared at Fort Keogh. Steers used were sired by either high-index Charolais bulls or average-index Hereford bulls. Three management groups, spring calves, fall-born yearlings, and spring-born yearlings, were penned by slaughter group (6/pen) and individually fed using an electronic gate system (Calan-Broadbent). Spring calves were weaned directly into the feedlot and were slaughtered at either 6 (weaning), 9, 12, or 15 mo of age. Fall-born yearlings were weaned onto pasture and then finished in the feedlot. Fall-born yearlings were slaughtered at either 14, 16, or 18 mo of age. Spring-born yearlings were weaned onto a growing diet during the winter, then went on pasture during the summer followed by finishing in the feedlot. Spring-born yearlings were slaughtered at either 18 (off grass), 19.5, 21, or 22.5 mo of age. Four steers of each sire type were slaughtered for each management-age group.

Steers were slaughtered at Miles City Packing Co. under a research cooperative agreement with Fort Keogh. Ground rib, ground carcass, and slices of longissimus dorsi muscle (LD) at the 12th rib were removed and sent to the University of Wyoming for analyses. Only LD data are reported in this summary. Visible depot fat was dissected from 5 to 10 grams of LD which was then freeze-dried, ground, and triplicate 0.1 gram samples extracted of all lipids. Cholesterol and fatty acids were separated by using standard procedures. Cholesterol content and fatty acid composition were determined by using a gas chromatograph.

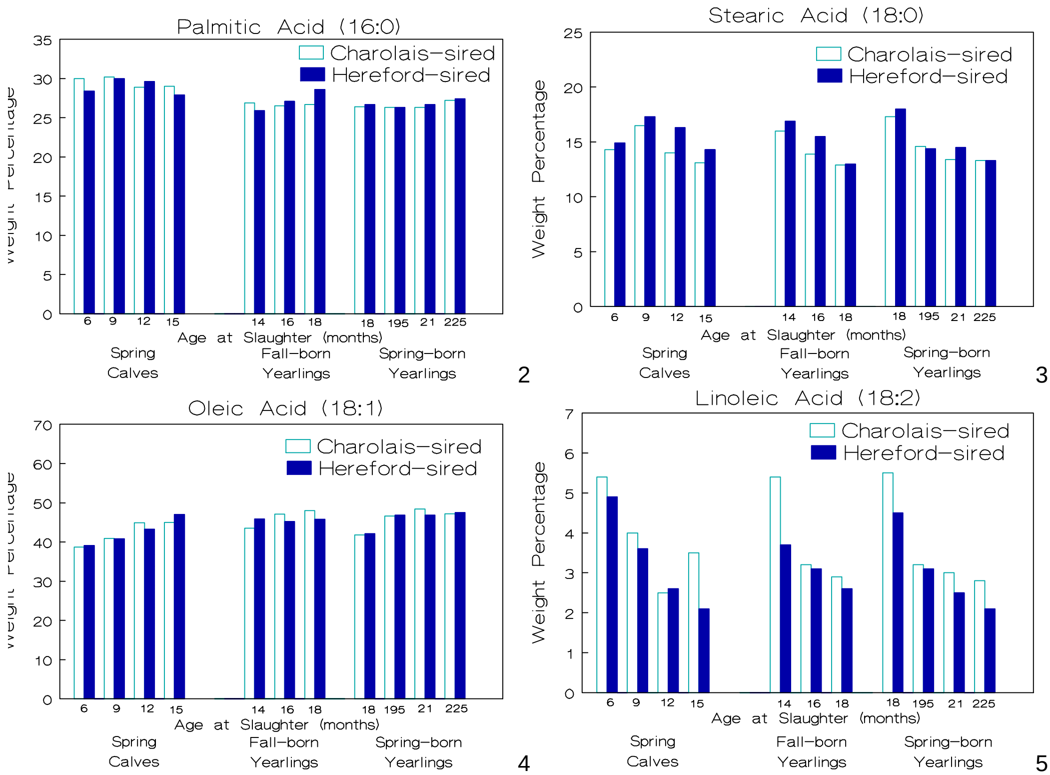

Figure 1. Fatty acids of 12th rib slices from Charolais- and Hereford-sired steers.

Results

Data in Figure 1 illustrate sire type and management effects on only 4 fatty acids: palmitic acid (a 16-carbon, saturated fatty acid, 16:0), stearic acid (18:0), oleic acid (an 18-carbon monounsaturated fatty acid), one carbon-carbon double bond (18:1), and linoleic acid (18:2). These fatty acids, which typically represent 80-90% of all fatty acids, were chosen for presentation because they are those with the greatest relevance to cardiovascular health in humans.

For the Charolais-sired steers within each management group, 16:0 was not affected by length of time in the feedlot and stearic acid (18:0) tended to decrease with time in the feedlot. This decrease in 18:0 appeared to have been countered by increases in oleic acid (18:1) which were generally observed for each management group. Linoleic acid (18:2) is usually very low in muscle of cattle. This fatty acid was greatest in the 12th rib LD upon entering the feedlot and decreased to roughly half within a relatively short time on their feedlot regimen. For the Hereford-sired steers, palmitic acid was more variable in this group than in the Charolais-sired steers. In spring calves, this acid tended to increase with time on feed and then decrease by 15 mo of age. In fall-born yearlings, on the other hand, 16:0 increased at each slaughter point, whereas essentially no variation with time on feed was observed in spring-born yearlings.

Changes in 18:0 were essentially opposite those of 16:0. Oleic acid in Hereford-sired spring-born calves increased with time in the feedlot, but no change with time in the feedlot occurred in fall-born yearlings. In spring-born yearlings, 18:1 only increased in steers from 18 to 19.5 months of age. Linoleic acid steadily decreased with time in the feedlot much like it did for Charolais-sired steers.

Cholesterol of LD rib slices was much more variable than fatty acids were (Fig. 2). Cholesterol in spring calves and fall-born yearlings was not affected by time in the feedlot. However, in spring-born yearlings, cholesterol content was greater at 18 mo of age than at 19.5, 21, or 22.5 mo of age. In Hereford-sired steers, rib slice cholesterol content appeared to have increased with time in the feedlot for fall-born yearlings but not for spring calves or spring-born yearlings.

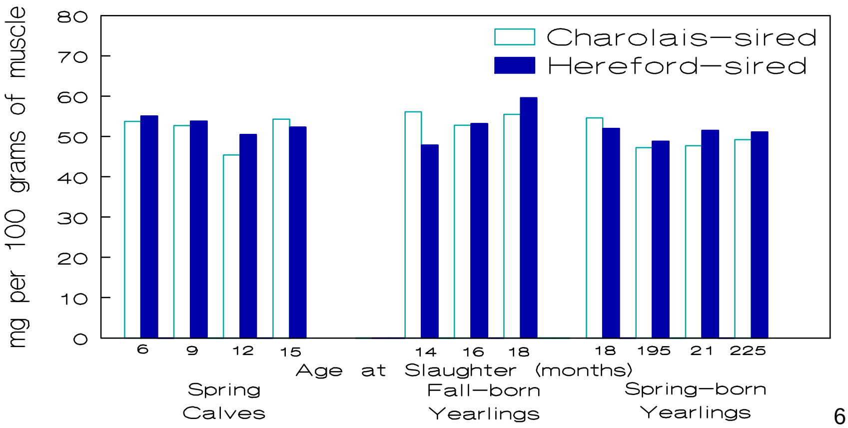

Figure 2. Cholesterol content of rib slices from Charolais- and Hereford-sired steers.

Conclusions

We found that 18:0, 18:1, and 18:2 fatty acids varied with different rearing methods, whereas 16:0 did not. In response to consumption by humans, 16:0 has been shown to be hypercholesterolemic (raises blood cholesterol). Decreases in this fatty acid would have been encouraging, but, on the other hand, no consistent increase was observed. Stearic acid decreased in all groups with time on feed. This fatty acid is currently regarded as neutral with regard to its impact on human cardiovascular health. Oleic acid increased, for the most part, with time on feed for both groups of steers. This was a positive result because 18:1 is a hypocholesterolemic (lowers blood cholesterol) fatty acid in humans. Linoleic acid decreased with time on feed for cattle of both groups, probably because consumption of forage decreased when cattle were placed in the feedlot. Because 18:2 is a hypocholesterolemic fatty acid, this result was not positive.

Management resulted in variable cholesterol content without trend towards lesser or greater amounts. Values are, however, somewhat lower than have been reported in other literature, probably because of the method used to measure cholesterol. By using gas chromatography, interfering substances can be separated. Other methods, for example those that involve a color reaction, measure light absorbance, so if interfering substances contribute to color development, higher values will be recorded. A comparison of procedures is currently in progress in this laboratory.

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The Cowbox: Will it Work?

R.E. Short, B.K. Knapp, L.O. Crosby, W.E. Larsen, and H.R. Duke

Introduction

The cowbox is an instrument we are attempting to develop to accurately estimate volume of live cattle. The technical name of this instrument is a plethysmometer, but for obvious reasons (without looking again, can you pronounce and spell the word?) we normally refer to it as a cowbox. This instrument estimates the volume of an object (in our case cattle) based on an old physics principle: when air is injected into an air tight chamber, air pressure will rise in proportion to the size (volume) of any object in the chamber. We are interested in estimating volume because the ratio of weight to volume (i.e., specific gravity) is related to how fat an animal is. This is because fat has a lower specific gravity than muscle and bone so as an animal gets fatter, its specific gravity decreases. 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.

We are interested in composition because it is important in determining quality of meat and production efficiency. It is assumed generally that there is an optimum amount of body fat that is needed to insure that the quality of meat produced in slaughter animals and the production efficiency of brood cows are maximized. Determining optimum management and breeding schemes would be easier if we could estimate the composition in live animals as accurately as we can estimate the composition of slaughtered animals. To this end, we have been evaluating several options for determining composition in live cattle. These options include body measurements (condition score, weight, hip height, and heart girth), ultrasound scanning, urea dilution, and plethysmometry. Body measurements and ultrasound scans have proven to be useful aids in predicting body composition, urea dilution has not, and the cowbox results are encouraging enough to continue. The problems with urea dilution (urea dilution estimates composition by knowing that fat is low in water as compared to muscle) are that it is invasive (injections and blood samples), slow (laboratory analysis of blood samples required), and improvement in precision of estimating composition is low.

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 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 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, as discussed earlier, is usually referred to as the "cowbox." 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 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.

As reported at the last field day, we collected a data set from 8 mature cows, 8 two-year-old steers, and 16 yearling steers that were fed a moderate or high energy ration to result in a range of body condition scores (BCS) from moderate (4-7) to high (7-10). This set of crossbred cattle was used to evaluate the accuracy of the cowbox for estimating body volume, specific gravity, and composition. Each animal was assigned a BCS by 3 trained technicians before being weighed and "cowboxed" 3 times each day for 3 days. The data were analyzed to get an estimate of repeatability (measurements must have high repeatabilities to be any good) and correlation with composition. The cattle were slaughtered at Miles City Packing Company under a cooperative research agreement that enabled us to obtain ground samples from the entire animal. This unique arrangement with Miles City Packing Company enabled us to collect samples whereby we could accurately determine the composition of the whole animal by chemically analyzing these samples.

Table 1. Correlation coefficients among various live animal measurements and actual body composition of slaughtered animals.

	Live Animal Parameters						
Actual Amount of Body:	Condition Score	Volume	Weight	Specific gravity	Back fat	Hip height	Heart girth
Water	-.77	-.64	-.64	.57	-.69	-.37	-.70
Fat	.79	.60	.60	-.46	.66	.12	.58
Protein	-.08	.01	.01	-.12	-.01	.35	.12

Results

Repeatability of the body volume measurements derived from the cowbox was high (.968) but less than that for body weight estimates (.998). The study results also revealed (Table 1) that some strong relationships existed between the various live animal variables estimated before slaughter and actual composition of the animals as determined after slaughter. For example, the analyses showed that total amount of body fat was positively correlated (i.e., related) with live animal condition scores as assigned by the trained technician (r=0.79), their volumes as determined from the cowbox (r=0.60), their weights as determined from weight scales (r=0.60), amount of back fat as determined by ultra-sound technology (r=0.66), and their measured hip heights (r=0.12) and heart girths (r=0.58). In contrast to these positive relationships, the results showed that the specific gravity (i.e., the ratio of the animal's weight to their volume) of the animals were negatively related to amounts of body fat (r=-0.46). In other words, these results show that as the fat composition of the animals increased, their specific gravity decreased. Additional analyses revealed that specific gravity estimates significantly increased the precision of estimate of total body composition in multiple regression analyses estimates.

Discussion and Conclusions

The data from this experiment were encouraging enough to continue evaluating the cowbox as an aid to our research. But progress has been slow for a number of reasons. For example, the door and piston seals and the transducer have all failed since this trial was completed and many problems surfaced with room and chamber temperatures. Also, we have become more aware of complications caused by animal breath cycles, animal movement, room and chamber noise, and pressure changes in the room caused by opening or closing room doors. Most of these problems have now been corrected or minimized by new door seals, a redesigned air injection cylinder, a new transducer, a change in room heaters, and a change in computer programming. We are now able to obtain repeatable data and are collecting data from 2 different studies where body composition is being determined. Slaughter of these cattle will be completed this summer.

We also recently became aware of a research project at the University of California that has developed a similar instrument for use in humans. Through our initial contact with those researchers we found that it is working well in that application, and they have been issued a patent. Thus, we are encouraged.

Rangeland Management Research at Fort Keogh: A Historical Perspective

M.R. Haferkamp

Introduction

Range management research was initiated at Fort Keogh by the U. S. Forest Service in 1932. The first research focused on quantifying the effects of various stocking rates on the rangeland vegetation and cow-calf production. Since then, a wide array of studies has been conducted; all of which were designed to assist management personnel in their attempt to garner a living from the land while maintaining the highest level of stewardship possible. The objective of this paper is to broadly review the findings from these earlier studies.

Grazing Management

The first grazing study was begun in 1932. Two sets of pastures were used in this 24-year study with one set grazed for 6 months during winter and the other for 6 months during summer. Stocking rates averaged 1.6, 2.6, and 3.25 ac/AUM (animal unit month) for the heavy, moderate, and light grazing treatments, respectively. Response parameters monitored included basal area cover of vegetation, vegetation height-weight relationships, efficacy of sagebrush and cactus, changes in soil bulk density, organic matter content, water infiltration rates, and livestock performance.

Study results were published in several publications during the period from 1935 to 1970. Researchers concluded that moderate stocking at 2.6 ac/AUM (30.5 ac/cow yearlong) was advantageous to vegetation, soils, and livestock and that at this rate about 55% of the western wheatgrass plants were grazed on hills and uplands. The 30.5 ac recommendation was used extensively by producers and government agencies to establish appropriate stocking rates on Northern Great Plains rangeland. Use of this standard improved range management practices in the region by reducing rates of soil loss, increasing plant growth, and ultimately increasing production of both domestic livestock and wildlife.

Because amount and distribution of precipitation varied widely during this study, considerable information was derived concerning the impact of drought on the grassland vegetation. Primary effects of the extended drought of the 1930's were to reduce the total basal cover of vegetation, heights of grasses, production of palatable herbage, and livestock performance. Current year basal areas were found to primarily reflect moisture conditions during the previous growing season; whereas, mature height of grasses and production of herbage were more closely associated with current growing season precipitation. Of the major plant species, basal areas of Sandberg bluegrass increased during and decreased after the drought; whereas, those of bluegrama and western wheatgrass decreased and then increased slowly. Results showed also that reductions in the basal areas of threadleaf and needleleaf sedges, prairie junegrass, and buffalograss during the drought were less dramatic than for bluegrama and western wheatgrass and that recovery was more rapid. Prickly pear cactus and dominant shrubs were also sensitive to the drought conditions.

Prickly pear increased rapidly on all ranges immediately following the drought but then decreased again after 1940. This decrease coincided with a period of damp-cool weather during which other vegetation was approaching predrought status. Silver sagebrush decreased 50 to 100% with drought. Reestablishment was rapid on bottomlands after 1938, and by 1943, plant densities were 7 times greater than predrought densities. Big sagebrush also decreased with drought, and by 1938, 64 to 85% of the plants were dead. Post-drought recovery on upland sites was not as rapid as for silver sagebrush on bottomlands. Researchers reported also that heavy grazing appeared to favor proliferation of silver sagebrush but that it was detrimental to big sagebrush.

It was from these early findings at Fort Keogh that researchers first begin to realize that changes in perennial grass cover often follow very complex patterns that are highly variable. Weather, plant species composition, kind of grazing animal, and possibly other factors were found to modify temporal patterns of degradation and recovery. They found that responses in amount and composition of vegetation may be relatively insensitive for judging adequacy of management on these ranges over periods as short as 3 to 5 years. On the other hand, they found that the size and growth characteristics of many grasses appeared to be sensitive and reliable indicators of changes in range condition, with dwarfing or decrease in height occurring similarly with unfavorable weather or overgrazing. Researchers also concluded that natural increases and decreases of prickly pear were caused by weather and that fluctuations in density of sagebrush were more suited to evaluating long-term rather than short-term trends. They cautioned against the indiscriminate use of fringed sagewort as an indicator of range condition because severe range deterioration may occur long before increases in fringed sagewort are apparent. Researchers also reported that reductions in surface litter, soil porosity, organic matter content, rate of water infiltration, and depth of rainfall penetration occur during early stages of range deterioration long before changes in vegetation parameters are markedly apparent. They hypothesized these effects may carry over for at least 1 year following complete rest from grazing.

Researchers found also that grasshoppers as well as cattle selectively prefer current year's green vegetation to carry over herbage. They found grasshoppers often ate the new high quality herbage as rapidly as it grew, leaving only low quality old herbage for livestock. Grasshopper's affinity for grasses during drought was further explained by cooperating scientists in the 1970's. They found that grasshoppers detect and preferentially feed on grasses treated with the amino acids proline and valine, which commonly increase in plants under drought stress. Results suggest this ability might lead to insect concentrations on drought-stressed and nitrogen-enriched plants.

Research at Fort Keogh during the 30's and 40's also showed that drought induced losses in forage production severely impacted livestock performance. Drought not only resulted in depleted ranges and light weight cattle but also greatly increased costs of production by increasing the need for supplemental feeding and reducing returns from cattle sales. Reductions in livestock performance (e.g., reduction in calf birth weight, rate of gain, weaning weight, weaning grade, cow fertility, and spring and fall weights of dry cows) were more dramatic on heavily stocked compared to moderately or lightly stocked ranges. Research showed calves produced on heavily grazed pasture failed to attain weights equal to contemporaries from moderately and lightly grazed pastures even when fed hay free choice their first winter. Animals still suffered setback at 18 months of age after being fed free choice hay in winter and grazed on lightly stocked range the second summer.

In another early grazing study (1936-1941), researchers found that a minimum of 5.4 ac were required for an 8-month period beginning in March for normal development and maintenance of a dry yearling ewe. Resulting utilization (percent of plants grazed, stubble height) was 45%, 0.6" for blue grama; 35%, 2.5" for western wheatgrass; and 35%, 0.8" for threadleaf sedge.

Few grazing studies were conducted at Fort Keogh during the 1960's and 1970's. However, in the 1980's, researchers again initiated grazing studies designed to evaluate the impact of various range improvement practices on yearling steer gains during summer. Study results revealed that gains often peaked in late July to early August and then decreased thereafter. Results revealed also that some increase in gains could be expected with certain improvement practices.

In summary, Ellison and Woolfolk concluded that "proper" grazing intensities for the Northern Great Plains are those that insure a forage reserve is accumulated on an annual basis during "normal" years. They concluded that such an accumulation would provide protection during future droughts and encourage rapid post-drought recovery. This concept is as important today as it was in the 1930's as drought continues to be an important factor affecting the structure and function of grassland ecosystems including Northern Great Plains rangelands.

Range Improvement Practices

Range seeding. Increasing forage production on rangelands has always been an important concern in rangeland environments. Research at this and other stations has been designed to determine relationships between environment and both desirable and undesirable plant species and to develop methods of range seeding, soil tillage, fertilization, and weed control that will enhance production.

Adaptation trials comparing plant species and varieties have been conducted for many years at the Station. Of the many species evaluated at Fort Keogh, crested wheatgrass and Russian wildrye have proven to be the 2 most productive introduced perennial grasses evaluated in that both provide large amounts of high quality, cool-season forage, and as such, fit well into complimentary grazing schemes with native range. Both of these species and the dominant native grass, western wheatgrass, were found to survive the drought in the early 1980's better than many of the grasses that were currently being recommended for rangeland seeding. However, during the drought of 1988, stands of crested wheatgrass and Russian wildrye were found to decline. In other studies, both of these species, when seeded alone or with alfalfa and used as spring range, were found to be highly productive which resulted in increased livestock weight gains and in some cases improved reproductive efficiency.

During the 1980's, researchers working cooperatively with ARS plant breeders in Logan, Utah, evaluated early generations of `Newhy' a bluebunch wheatgrass x quackgrass hybrid. Results show this hybrid is well adapted to growing on saline soils that have been seeded historically to tall wheatgrass. But, in contrast to tall wheatgrass, hybrid plants are leafier, more palatable, and maintain a higher forage nutritional value into fall. Researchers at this location identified lines that were selected most frequently by steers and the characteristics of the plants associated with this preference. Variables such as basal area, height, phenology, leafiness, silica content, and digestibility were related to preference in some but not all trials. Carbohydrate content was also related to preference in some trials. Work was continued with this hybrid into the late 1980's to evaluate response of plants to fertilizer, defoliation by mowing, and irrigation. Researchers concluded that irrigated, nitrogen fertilized pastures of RS-2 harvested in midsummer, rested, and utilized again in fall or early winter should provide large amounts of high quality forage for grazing livestock in the Northern Great Plains.

Seedling establishment is a critical phase in establishing a productive seeding. Cool-season perennial grasses are often planted in late fall before soils freeze. In these dormant plantings, seeds germinate as the soil thaws and seedlings emerge thereafter. Research in the early 1980's showed that winter damage and the subsequent number of viable leaves present when growth began in spring were highly correlated with amount of spring and fall seedling growth in crested wheatgrass, Russian wildrye, and pubescent wheatgrass. As number of leaves increased from 1 to 4 during spring there was a corresponding increase in subsequent growth. Results suggested seeding in late summer in the Northern Great Plains would hasten stand establishment and reduce the length of grazing deferment necessary on newly seeded stands. However, the key to success with this seeding strategy is availability of adequate subsurface moisture that will allow seedlings to reach their optimal growth stage after germinating in late summer or fall. The amount of subsurface moisture required has not been quantified. As for optimal stage of development, no seedlings with more than 2 leaves died during winter and no seedlings with more than 3 leaves showed heavy or severe damage. Decrease in winter damage leveled as plants attained 3 leaves and as heights reached 2.6". This study was conducted during a winter with above average snowpack, and an open winter may provide different results.

Seeding techniques that improve stand establishment are constantly in demand. The Range Improvement Machine (RIM) developed by Currie and Erickson in the early 1980's showed potential for enhancing establishment of seeded stands on Northern Great Plains rangelands. Seedling establishment was significantly greater with the RIM compared to a power-till drill. The RIM created a relatively competition free seedbed furrow. Measurements from other studies using the RIM showed that treated areas enhanced soil water infiltration and retention.

Soil tillage and furrowing. Several methods of modifying rangeland soil surfaces have been evaluated at Fort Keogh. Range pitting was shown to reduce soil moisture stress and subsequently increase forage production on overflow and clayey range sites during a 6-year study in 1957-62. Contour furrowing was apparently first utilized to improve forage production at Fort Keogh during the drought of the 1930's, but the effects of such were not quantified until it was used in studies in the 1970's and 1980's. In one 5-year study, from 1974 through 1978, forage production was increased on an upland, medium textured range site from 538 lbs/ac on nontreated native range to 1206 lbs/ac with contour furrowing and seeding alfalfa. Furrowing applied with a contour furrower or the RIM effectively increased forage production during an 8-year period from 1983 to 1990. A series of treatments applied with the contour furrower or RIM machine produced June standing crops which averaged 286 lbs/ac greater than the 518 lbs/ac produced on the control pasture. Soil tillage and furrowing techniques were most effective on the heavier textured soil. Results showed the techniques increase production by holding moisture on site. Researchers also hypothesized that the increase was related to a releasing of nitrogen from destroyed vegetation. In some cases, soil nitrogen has been further enhanced by fertilization, seeding legumes, or both. These increases in forage production have resulted in some increases in livestock production when compared to untreated native range. In related studies on these pastures, researchers found also that sagebrush removal and interseeding of legumes did not markedly affect total grasshopper population trends but did influence species composition and provided additional food plants for some species.

Water enhancement. Beginning in 1936, water spreading systems were developed by building diversion dams and contour dikes. These studies were among the first in the U.S. to demonstrate that water normally lost to run-off could be used effectively to increase growth of native and introduced grasses. Research by cooperating agencies was conducted on the Station in the early 1980's to determine the response of vegetation to water availability at levels (0.24", 0.48", or 0.98"/wk) that might be applied through irrigation or cloud seeding. In a study with western wheatgrass, they found plant culm length was increased 6 to 7% with light showers (0.24 - 0.39") and 33-107% when soils were kept moist, but aboveground yields were significantly increased only by the wet treatments. Others reported in associated studies that water deposited from natural summer rainfall on these grasslands is likely to be lost in less than 2 days because 92% of the rain showers are <.4".

Fertilizer applications. Fertilization with nitrogen has been an effective method to obtain relatively rapid increases in forage production, particularly on overflow range sites. Research at Fort Keogh has shown that applying 30 lbs N/ac to native range may be economically profitable in some years. Nitrogen has also been applied in combination with other treatments such as contour furrowing. In one 5-year study, forage production on an upland medium textured range site ranged from 538 lbs/ac on nontreated native range to 1206 lbs/ac with contour furrowing and seeding alfalfa. Additions of 100 lbs/ac of nitrogen and 13.4 lbs/ac of phosphorous on interseeded range increased herbage production to 1480 lbs/ac. Average beef production over the 5-yr period was 20 lbs/ac on the control, 39 lbs/ac on the contour furrowed range, and 47 lbs/ac on the contour furrowed-fertilized range.

Burning. Burning has been used effectively in other regions to manage undesirable plants and increase herbage production. Burning in spring or fall was studied in the early 1980's at Fort Keogh to determine its effect on increasing production of grasses and decreasing stands of silver sagebrush. Results showed that spring burning with good soil moisture resulted in low mortality of silver sagebrush; whereas, fall burning with low soil moisture resulted in considerable mortality and reduced shrub growth. As fire intensity increased, mortality increased and regrowth decreased. Data from a study conducted in 1983 suggested spring burning of western wheatgrass and blue grama stimulated herbage production by mid- and late June; whereas, fall burning also stimulated herbage production but to a lesser degree. However, earlier season herbage production was not enhanced by this burning treatment. Researchers at Fort Keogh have shown that greatest reductions of downy and Japanese brome occur with fall burning, but good reductions are obtained with spring burning. When bromes were reduced, the remaining blue grama outproduced that growing in control plots. In general, the results from these studies showed that fire appears to be an effective tool for managing vegetation in this area of the Northern Great Plains.

Herbicides. Very few herbicide studies have been conducted at the Station. This reflects a lack of large amounts of undesirable plants that are actively competing with native vegetation. Houston and Woodward wrote: "These ranges appear resistant to extreme reduction in range condition due to heavy stocking. It would seem that the composition and vigor of the native vegetation under prolonged heavy grazing and below-normal precipitation are considerably reduced, but then they tend to stabilize at a low but fairly constant level. At this level, competition is still sufficient to prevent large-scale replacement by invader species. The increase of sod species under heavy stocking is probably the primary reason for this."

However, annual bromes have invaded ranges in this region, and some of the more aggressive perennials are present in varying densities. Thus, the use of soil-active herbicides has been studied at Fort Keogh as a method of controlling annual bromegrasses in seeded stands of crested wheatgrass, pubescent wheatgrass, Russian wildrye, and native rangeland dominated by western wheatgrass and blue grama. Results showed yields of annual bromegrasses averaged 91 and

47% less than controls the first and second year post treatment. Averaged over 4 study sites, bromegrass yields in 1983 and 1984 were 88 and 50, 88 and 8, and 94 and 84% less than the control in the atrazine, propham, and pronamide treatments. Yields of perennial grasses were increased from treatment the first year post treatment.

Most efforts at the Station and other locations to control brome have been shown to provide only short-term relief. Thus, current research is underway to gain a better understanding of the impact of Japanese brome on Northern Great Plains rangelands. Ongoing studies are examining: 1) the environmental effects on annual brome seed germination; 2) the impact of brome competition on western wheatgrass production; 3) the effect of brome on quantity and quality of forage produced and on livestock production; and 4) the impact of defoliation and nitrogen on growth and development of Japanese brome.

Autecology. Plains silver sagebrush is an important shrub in the Northern Great Plains. It is found on deep, lowland soils of floodplains and is generally considered to increase in response to cattle grazing. There are about 12.8 million ac of silver sagebrush in Montana. In the early 1980's, studies were implemented to examine the reproductive characteristics and mechanisms which are important in the success and maintenance of plains silver sagebrush. They determined that wind appears to be the most influential factor in the dispersal of achenes from plants. Researchers also found seeds germinate under a variety of environmental conditions, but greater germination occurs: 1) from seeds collected late in the growing season; 2) in complete darkness compared to light when plants are under some water stress; and 3) at a temperature of 68^{o}F. All rates of germination declined with increasing water stress. Most plants, even small seedlings, showed some degree of rhizomatous (vegetative) growth. Phenological development, plant water potential, and soil water status were monitored on established plants. They determined phenological development could be predicted by using both plant water potential and calendar date.

Research at Fort Keogh has shown that weather has a far greater effect on abundance and vigor of plains prickly pear than any other influence investigated. Influences of weather tend to be cumulative up to a point, but weather may also have opposing influences. Precipitation is an important influence on the infestation of the prickly pear clumps by several insects, with some being favored by high and some by low precipitation. Thus, insect infestation is almost continuous. Data indicated that soil moisture and soil texture were most important soil characteristics, but topography or microenvironmental differences were also important. In one study there was an almost non-existent overall effect of stocking rate, at least in the range of 1.8 to 3.2 ac/AUM, on abundance and vigor of plains prickly pear. These findings were in contrast with findings of several other investigators. Stocking rates, however, interacted strongly with weather and soils in that a decrease in pads occurred on upland soils; possibly through trampling, soil compaction, and perhaps utilization. This reaction was, however, probably modified by weather.

Methods and Techniques

As in most phases of range research, development of techniques and equipment to assist in monitoring changes in vegetation and livestock performance is an ongoing process. For example, it was shown in the early 1950's that plant vigor, as expressed by the height of western wheatgrass plants, varied with range condition, amount of protection afforded by prickly pear, and annual precipitation regimen. The study established the utility of this system of measure of vigor as a criterion for the appraisal or estimation of range condition.

During the 1980's, several trials were conducted comparing different capacitance meters for estimating standing crops on native and seeded ranges on the Station. This work helped define the shortcomings of various meters and how plot size could be adjusted to obtain better relationships between clipped samples and meter readings.

Future

The range research program at Fort Keogh is actively investigating vegetation-environment-animal relationships. Specific ongoing studies include studies designed to: 1) elucidate the impacts of annual bromes on the quantity and quality of forage produced and consumed by beef cattle; 2) quantify the impact of annual bromes on livestock production; and 3) quantify the interaction effects of livestock grazing and drought on rangeland ecosystems in general and quantity and quality of forage produced, root growth, soil water dynamics, water quality, and seed bank dynamics specifically. These studies are designed to produce data that will provide a greater understanding of these relationships and will allow development of management strategies that will promote efficient and ecological sound use of Northern Great Plains rangelands.

Key Scientists Associated with Rangeland Research Program at Fort Keogh[1]

Name	Years at Fort Keogh[3]	Affiliation[2] or Position
R.W. Collins	1930's - 1940's	USFS
L.C. Hurtt	1930's - 1940's	USFS
L. Ellison	1930's	USFS
E.J. Woolfolk	1930's - 1950's	USFS
C.E. Holscher	1940's - 1950's	MAES
W.R. Houston	1950's - 1960's	ARS
R.A. Peterson	1950's	USFS
M.J. Reed	1950's	USFS
L.R. Short	1940's - 1950's	USFS
R.S. White	1977 - 1987	ARS
P.O. Currie	1978 - 1989	ARS
M.R. Haferkamp	1988 - present	ARS
R.K. Heitschmidt	1990 - present	ARS
J.D. Volesky	1988 - 1989	ARS
M.M. Borman	1989 - 1990	ARS
M.G. Karl	1990 - present	ARS
Current Rangeland Research Support Staff		
B. Bennett	1992 - present	Research Associate
C. Murphy	1978 - present	Bio. Lab. Tech.

[1] This list of personnel is admittedly incomplete. The reason it is incomplete is because historically much of the range research that was conducted at Fort Keogh was conducted by non-resident scientists, and in many instances, by non-USDA Agricultural Research Service employees. Thus, detailed documentation of most cooperating scientists' careers at Fort Keogh are either totally absent or at best incomplete.

[2] USDA Forest Service = USFS; Montana Agricultural Experiment Station = MAES; and USDA Agricultural Research Service = ARS

[3] Many estimates based on publication records.

Effects of Mechanical Treatments and Climatic Factors on the Productivity of Northern Mixed-Grass Prairie

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

Introduction

Livestock production from rangelands depends largely upon production of vegetation. To successfully increase livestock production often requires an increase in forage production. The broad objective of this research was to quantify the integrated impacts of soil tilling, legume interseeding, brush removal, nitrogen fertilization, and climate on herbage production of Northern Great Plains rangelands.

Methods

One control and 6 treated pastures were established in 1982 at 2 diverse range sites. Treatments included: 1) untreated control with season-long (SL) grazing; 2) soil tillage (ST) + SL; 3) ST + drill seeding legumes (DS) + SL; 4) brush control (BC) + ST + DS + switchback grazing (SB); 5) BC + ST + DS + SL; 6) ST + nitrogen fertilization (NF) + SL; and 7) contour furrowing (CF) + aerial seeding legumes (AS) + SL. Treatments were grazed during summer from 1983 through 1990. Grazing intensity was moderate with 3 to 5 steers allotted to each season-long pasture. Usually 10 steers grazed the SB pastures. Steers grazed the initial pasture until the midpoint of the grazing season and then were moved to the second pasture. The pasture grazed first was alternated each year. Date of grazing initiation varied among years (May 15 to June 10) depending on the spring growing conditions. Grazing was generally terminated after 90 days, but steers were removed earlier in drought years.

Herbage standing crops were estimated annually in all pastures just prior to the beginning of the grazing season by hand harvesting all herbage above a 1" stubble height in fifteen 1' X 2' plots per pasture. Because clipping dates varied among years, all data were adjusted to day 156. Total, species, and species group (Perennial cool-season grasses = PCSG; Sedge = CAFI; Annual grasses = ANGR; Other grasses = OTGR; and Forbs = FORB) standing crops were analyzed using year as a repeated measure.

Results

Treatments increased spring total standing crop an average of 286 lbs/ac over controls (Fig. 1). Differences among treatments were not significant, and species and species groups responded similarly between treatments. Established treatments produced similar standing crops of 789 lbs/ac. The largest components of the standing crops at both sites were western wheatgrass + Sandberg bluegrass and annual grasses.

Total standing crops averaged 438 lbs/ac more in 1983, 1986, 1987, 1989, and 1990 than in 1984, 1985, and 1988 (Table 1). Perennial cool-season grass standing crop was greatest in 1986 (581 lbs/ac). Standing crops of western wheatgrass averaged 470 and 391 lbs/ac in 1986 and 1987, and 277 and 410 lbs/ac in 1989 and 1990. Sandberg bluegrass standing crops were 18 and 29% of the perennial cool-season component in 1986 and 1989, respectively, averaging 110 lbs/ac.

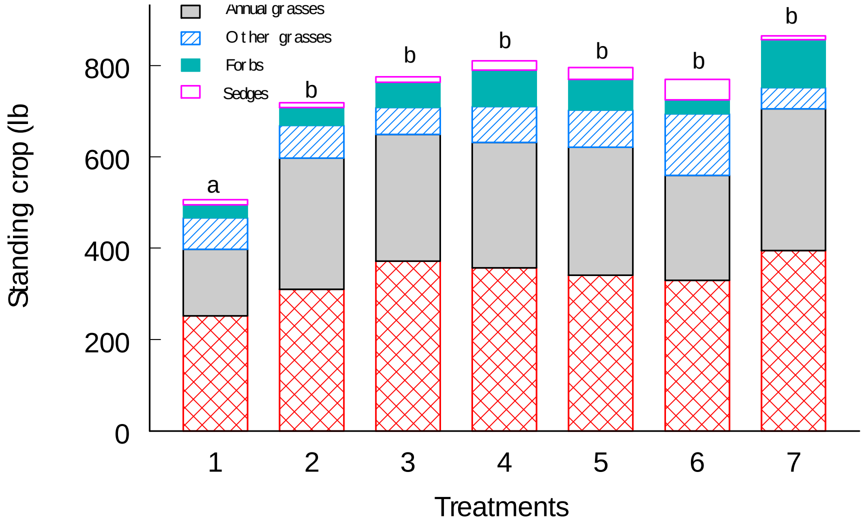


Figure 1. Least square mean herbage standing crops by treatment (see methods for treatment definitions) averaged across 2 sites and 8 years ($LSD_{0.05}$ - 178 lbs/ac). Means between columns, followed by the same letter, are not significantly different at ($P \geq 0.05$).

Table 1. Annual least square mean standing crop on 5 June by species/species groups averaged across 7 treatments and 2 range sites near Miles City, Montana.

	Species Groups					
	Grasses					
	W. Wheatgrass					
Year	S. bluegrass	Annual	Other	Sedges	Forbs	Total
	--- (lbs/ac) --					
1983	239d[1]	343b	210a	25	104	922ab
1984	170d	301bc	60b	16	27	573c
1985	196d	170d	52b	11	52	480cd
1986	581a	183d	74b	21	89	950ab
1987	434c	237cd	59b	18	69	816b
1988	246d	23e	53b	6	36	364d
1989	382c	373ab	51b	11	57	822b
1990	468b	452a	60b	27	51	1057a
	-------------------$LSD_{0.05}$ = 87 -------------------					

[1] Means within a column followed by same letters are not significantly different at ($P \geq 0.05$).

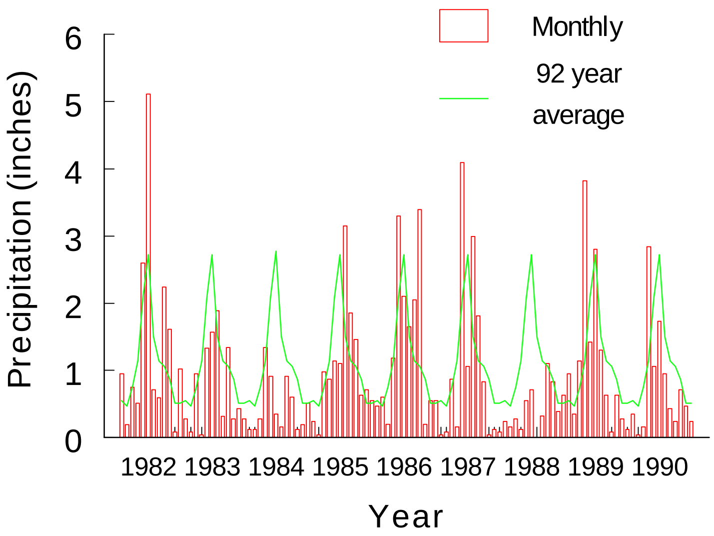


Figure 2. Actual (January-December, 1982-1990) and long-term (92 year) average precipitation for Miles City, Montana.

Annual grasses contributed 37 and 52% of the standing crops produced in 1983 and 1984 (Table 1). During the 2 years following the severe drought of 1988 (Fig. 2), annual grasses contributed 43%. Annuals, however, contributed only 6 to 29% of the standing crop in 1986 through 1988. Japanese brome and downy brome contributed 60 to 96% of the annual grass standing crop from 1984 to 1990. Japanese brome averaged greater than 50% of the annual grass standing crop in 1984, 1985, 1988, 1989, and 1990; whereas, downy brome averaged greater than 50% in 1986 and 1987.

Conclusions

We conclude from the results of this 8-year study that the mechanical disturbance of the soil surfaces was the dominant component of the 6 established treatments associated with the observed increases in herbage standing crop. Annual variations in climatic conditions tended to have a greater impact on standing crops than did the treatments. Maximum year to year effect in our study was about 1.6 times the treatment effects.

Definitive trends in species response to annual variation in climatic conditions were apparent. Forage production of Sandberg bluegrass tended to increase following drought, and both Sandberg bluegrass and western wheatgrass increased when fall and spring precipitation were above average. Standing crops of annual grasses were greatest the 2 years immediately following mechanical disturbance of the soil and the 2 years immediately following the severe drought of 1988. The permanence of the increase in annual grasses, particularly Japanese brome, that occurred following the severe drought in 1988 is unknown. It seems reasonable to assume, however, that annual grasses will continue to increase in stature throughout the northern mixed grass prairie particularly on areas where fire and/or intensity of grazing by large herbivores have been greatly reduced.

Recent Publications

Haferkamp, M.R. 1992. Mortality of crested wheatgrass and Russian wildrye during drought. J. Range Manage. 45:355-357.

Haferkamp, M.R. 1993. Effects of mechanical treatments and climatic factors on the productivity of Northern Great Plains rangelands. J. Range Manage. 46:346-350.

Effects of Mechanical Treatments and Climatic Factors on Livestock Production in the Northern Mixed-Grass Prairie

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

Introduction

There is little reason to implement various range improvement practices unless they increase net returns. Because installation of most, if not all, range improvement practices cost money, increased net returns are dependent on increased gross returns. Because livestock sales are the primary source of revenue from rangelands, gross returns are tied closely to livestock sales. The objective of this research was to quantify the effect of various "range improvement" practices on steer summer weight gains.

Methods

Six treatment and 1 control pasture were established in 1982 at 2 diverse range sites. Treatments included: 1) untreated control with season-long (SL) grazing; 2) soil tillage (ST) + SL; 3) ST + drill seeding legumes (DS) + SL; 4) brush control (BC) + ST + DS + switchback grazing (SB); 5) BC + ST + DS + SL; 6)ST + nitrogen fertilization (NF) + SL; and 7) contour furrowing (CF) + aerial seeding legumes (AS) + SL. Treatments were grazed during summer from 1983 through 1990. Grazing intensity was moderate with 3 to 5 steers allotted to each season-long pasture. Usually 10 steers grazed the SB pastures. Steers grazed the initial pasture until the midpoint of the grazing season and then were moved to the second pasture. The pasture grazed first was alternated each year. Date of grazing initiation varied among years (May 15 to June 10) depending on the spring growing conditions. Grazing was generally terminated after 90 days, but steers were removed earlier in drought years.

Diet quality was estimated in all treatments at both sites at the beginning and end of the 1987 and 1988 grazing seasons. Diets from 4 esophageally-fistulated steers per pasture were collected in early morning on each sample date. Steers were fasted for 14 h prior to sampling. Samples were ovendried at 140^{o}F and ground through a .04" screen prior to analyses for crude protein concentration and in vitro organic matter digestibility determinations.

Results

The results from this study showed that steer performance in each treatment was affected more by annual climatic conditions than it was by mechanical treatment of the rangeland. This is demonstrated in Tables 1 and 2. These results show also that there was a strong trend towards greater gains from within the various treatment pastures than the untreated control. This is in agreement with our findings that early season herbage standing crops were greater in the treatment than the control pastures.

Table 1. Steer performance for the 7 treatments averaged across 6 years.

Treatment[1]	ADG_F[2]	ADG_L[3]	ADG_T[4]	Gain $steer^{-1}$	Gain ac^{-1}
	----------	----------	(lbs)	----------	----------
1	2.2	0.2	1.1	56	12
2	2.2	0.2	1.3	90	15
3	2.2	0.7	1.3	99	18
4	2.0	0.7	1.3	93	16
5	2.2	0.9	1.5	112	20
6	2.2	0.7	1.3	99	17
7	2.0	1.1	1.5	106	19

[1] See text Materials and Methods for treatment definitions.
[2] ADG_F = average daily gains during first one-half of grazing season.
[3] ADG_L = average daily gains during last one-half of grazing season.
[4] ADG_T = average daily gains during entire grazing season.

Table 2. Steer performance (lbs) for 1983 through 1988 averaged across the treatments.

	Year					
Parameter	1983	1984	1985	1986	1987	1988
	----------	----------	---------- (lbs)	----------	----------	----------
ADG_F[1]	2.2	2.6	2.2	2.4	2.6	0.9
ADG_L[2]	0.2	0.9	0.9	0.4	0.4	0.9
ADG_T[3]	1.1	1.8	1.5	1.5	1.5	0.7
Gain $steer^{-1}$	108	108	62	143	137	22
Gain ac^{-1}	19	19	11	24	26	3

[1] ADG_F = average daily gains during first one-half of grazing season.
[2] ADG_L = average daily gains during last one-half of grazing season.
[3] ADG_T = average daily gains during entire grazing season.

The study results also reveal that quality of diets in the treatment pastures was not different than the quality of diets in the control pastures during the 1987 and 1988 grazing seasons. These data provide support for the idea that the major factor affecting livestock production in these treatment pastures was the quantity of forage available and not the quality of forage available.

Conclusions

The results from this study imply that installation of the 6 range improvement practices did tend to increase steer production but steer production was affected more by annual climatic conditions than range improvement practice. No conclusions can be made from this study relative to the economic benefits derived from the installation of the mechanical treatments.

Japanese Brome in the Northern Great Plains

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

Introduction

Japanese brome is an alien annual grass that has become a major component in some mixed prairie plant communities in the Northern Great Plains. Its life cycle is somewhat shorter in duration than perennial grass species commonly found as counter parts with it. Further, as with all annual grasses, annual forage production is erratic and when present on rangelands, it may shift the period of peak forage production and cause an early season decline in forage quality. Thus the presence of Japanese brome may negatively impact, livestock production.

Perpetuation of Japanese brome on rangelands requires completion of its annual life cycle beginning with seed germination, continuing through seedling emergence and establishment, and terminating with plant maturation and seed dissemination. Determining how environmental conditions affect life cycles of Japanese brome plants and their interactions with other plant species is critical for development of grazing management strategies to efficiently utilize brome infested rangelands.

To develop a better understanding of these relationships, we began a series of studies in 1991 designed to determine the effect of environmental factors on Japanese brome seed germination, the effect of Japanese brome presence on western wheatgrass, and the effect of clipping on herbage and root production of Japanese brome plants.

Methods

Germination. In germination studies we varied temperatures, collection dates, as well as storage and light conditions to simulate environmental conditions that might be encountered in the field. Seeds were collected in summer in Oklahoma and in summer, fall, and winter in Montana. Summer collections were stored in a laboratory, and fall and winter collections were divided into thirds, each of which was stored either in an unheated warehouse, freezer, or ovendried condition.

Summer collections were initially incubated in a series of 55 constant and alternating temperatures ranging from 32^{o}F to 104^{o}F which were divided into combinations related to selected seedbed environments. Summer collections from Oklahoma and Montana and fall and winter collections from Montana were incubated in 2 temperature regimes. A warm regime consisted of 28 days at alternating 12 hr periods of 46^{o}F and 73^{o}F, and a cool+warm regime consisted of 10 days at 32^{o}F and 50^{o}F and 18 days at 46^{o}F and 73^{o}F. The summer, fall, and winter seeds were also incubated at 46^{o}F and 73^{o}F in total darkness or alternating 12 hr periods of light and dark.

Competition. In competition studies, 3 treatments were applied. Either all plants were left intact in a circle with a 3'8" diameter, a portion of the Japanese brome plants were removed (.50%), or all Japanese brome plants were removed. Removal of Japanese brome plants occurred during late spring and early summer. In early July, biomasses of western wheatgrass, Japanese brome, and all other vegetation were sampled to ground level in a circle with a 1'9" diameter located in the center of each plot.

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

Results

Germination. Mean germination for the 55 temperature regimes for Japanese brome was 71% (Table 1). Over 95% of all temperature regimes supported some germination, and the mean germination for regimes where some germination occurred was 74%. Optimum germination occurred in 32% of the regimes and mean of optima was 99%. The maximum germination was 100%.

Table 1. Germination characteristics of Japanese brome seed collected in Montana in summer 1990-91.

Characteristic	Japanese brome
Mean germination (%)	71 (4.2)[1]
Mean germination of regimes with some germination (%)	74 (4.3)
Regimes with some germination (%)	96 (1.4)
Regimes with optimum germination (%)	32 (8.0)
Mean of optima (%)	99 (1.1)
Maximum germination (%)	100 (1.1)

[1] Means and standard deviations based on eight replications.

Maximum germination of Japanese brome seed occurred at moderate and cold seedbed conditions, with germination being somewhat depressed in very cold and warmer than moderate temperatures (Fig. 1). Responses were similar between years.

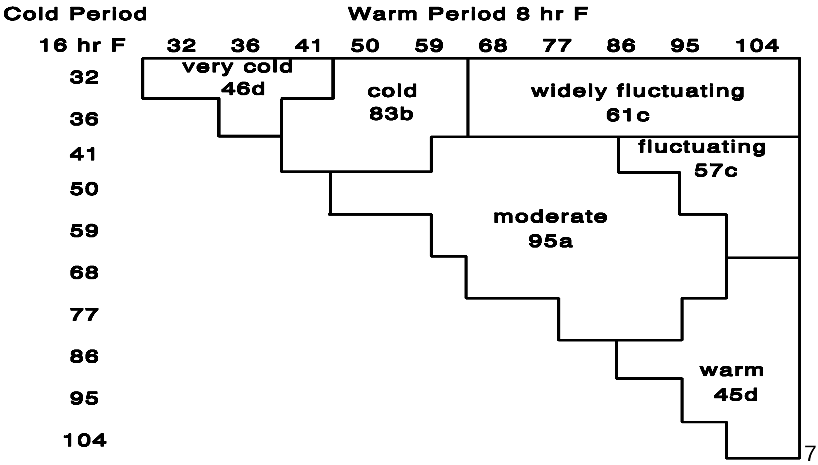


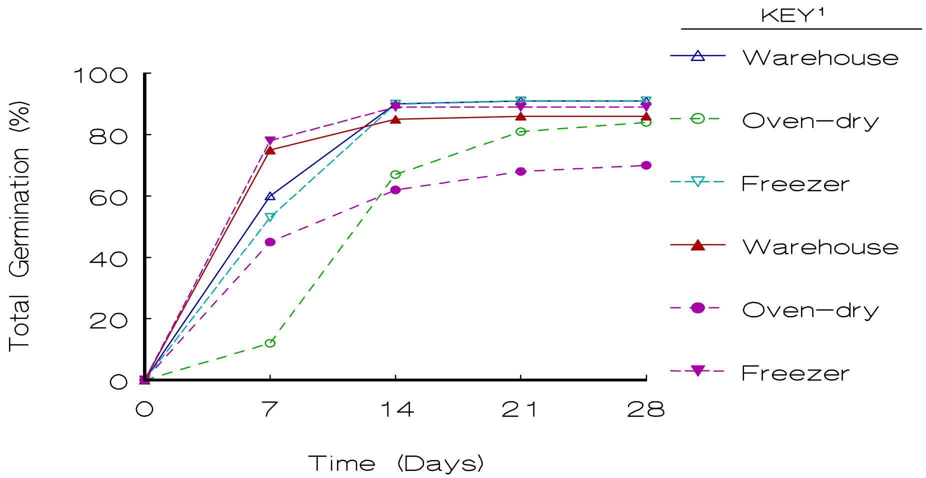
Figure 1. Seedbed requirements of Japanese brome seed collected in Montana in summer 1990-91. Mean germination followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's Multiple Range test.

When summer, fall, and winter collections were compared, summer collections germinated rapidly to greater than 90% regardless of temperature (Table 2). Fall and winter collections stored in the warehouse germinated greater than 70% in the warm regime, but germination was reduced to less than 20% in the cool+warm regime, suggesting these seeds may have entered a dormant state when incubated at 32^{o}F.

Table 2. Maximum germination in 2 temperature regimes for Japanese brome seed collected in Oklahoma and Montana in summer 1991 and in Montana in fall and winter of 1991. Summer collections were stored in a laboratory, and fall and winter collections were stored in an unheated warehouse.

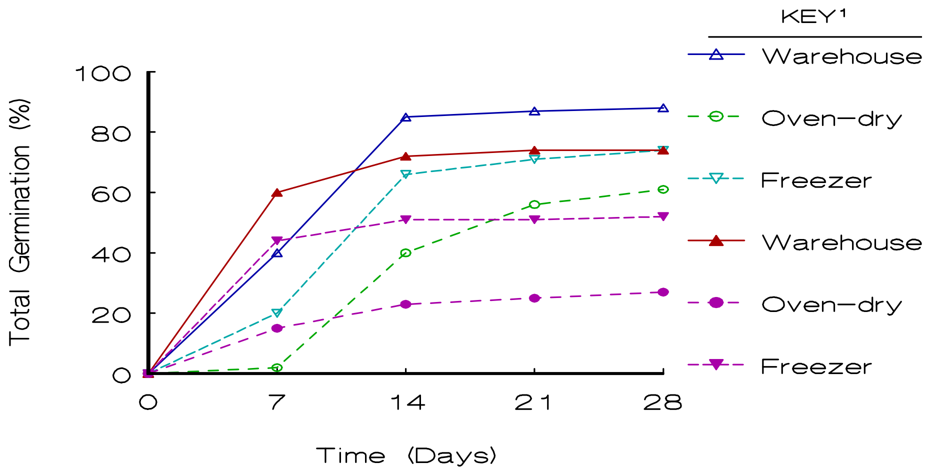
	Okla.	Mont.		
Temperature	July 7	July 12	Nov. 21	Dec. 30
	-- (%) --			
32 - 50^{o}F + 46 - 73^{o}F	99	92	18	5
46 - 73^{o}F	100	100	88	71
		LSD$_{0.05}$ = 4.3		

When the presence of light was studied, we found darkness, as might be encountered under a dense litter cover, enhanced 7-day germination by 0 to 35%, but light improved 28-day germination by 0 to 31%, and winter collected seeds were more sensitive to light than fall collections (Figs. 2 and 3). If oven-dried seeds are excluded, over 40% of the seeds collected in fall and winter and over 90% of the summer collections germinated in darkness.



[1] Open symbols = incubation in light; Filled symbols = incubation in dark.

Figure 2. Germination of Japanese brome seed collected in November, stored in an unheated warehouse, oven-dried or frozen, and incubated for 28 days in a 46-73^{o}F temperature regime in darkness or with alternating light for 12 hours at the high temperature.



[1] Open symbols = incubation in light; Filled symbols = incubation in dark.

Figure 3. Germination of Japanese brome seed collected in December, stored in an unheated warehouse, oven-dried or frozen, and incubated for 28 days in a 46-73^{o}F temperature regime in darkness or with alternating light for 12 hours at the high temperature.

Competition. Trends suggest western wheatgrass production was reduced with the presence of Japanese brome, but the reduction was not significant in 1991 (Fig. 4). In 1992, standing crop of western wheatgrass was reduced by presence of Japanese brome but not by partial removal when compared to total removal. Total standing crop was significantly reduced during both years by an average of 284 lbs/ac at 1 location and 643 lbs/ac at the other by the total removal of brome. Results from 1991 and 1992 differ in the significant response of western wheatgrass to Japanese brome removal. Precipitation was probably the most important factor affecting this relationship. Total precipitation during April, May, and June of 1991 (13.2" or 203% of normal) was 3 times the amount received on either site in 1992 (4" or 62% of normal).

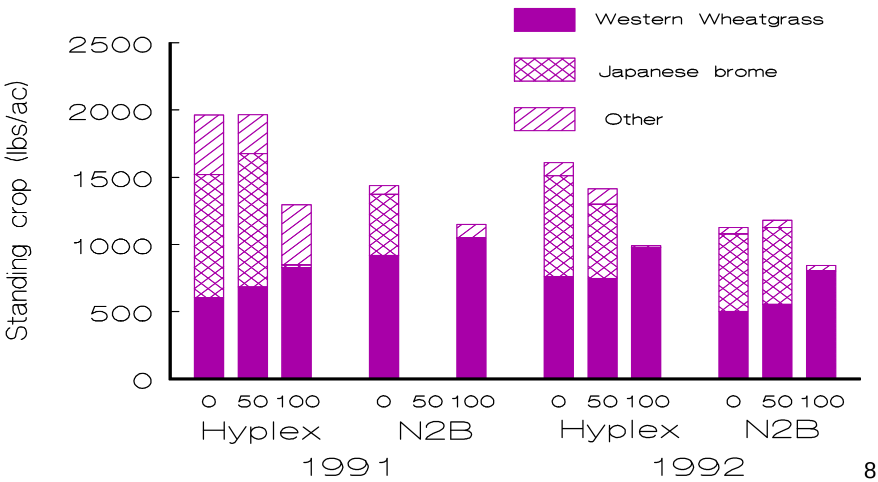


Figure 4. Peak standing crops of western wheatgrass, Japanese brome, and other species growing in competition plots in 1991 and 1992 at the Hyplex and N2B sites on Fort Keogh. Japanese brome was removed at 0, 50, and 100%.

Simulated Grazing. In 1991, plants in the clipping study remained vegetative throughout. Japanese brome plants require vernalization or exposure to short day lengths to become reproductive. Outside lighting prevented this treatment in 1991. Clipping in any form reduced production of roots, herbage, and total biomass (Fig. 5). Increasing the intensity of clipping significantly reduced herbage and total biomass, and although similar trends occurred with root biomass, differences were not significant. Increasing the frequency of clipping from every 2 weeks to weekly did not significantly reduce biomass production.

In 1992, plants produced reproductive shoots. Increasing intensity of clipping significantly reduced total herbage weight and reduced total biomass for all but the plants clipped to 6" every 2 weeks (Fig. 5). Root weights were similar for nonclipped controls and both clipping frequencies at 6", but weights were significantly less for plants clipped at 3". Weight of inflorescences was greatest for nonclipped controls. Frequency of clipping did not generally affect any component as much as intensity of clipping.

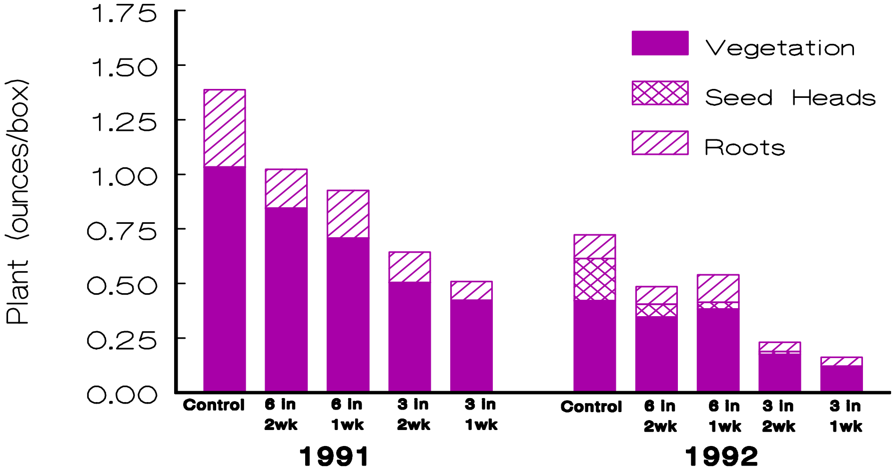


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Figure 5. Weights of herbage, seedheads, and roots produced by nonclipped controls of Japanese brome plants grown in the greenhouse and plants clipped at 3 or 6 in on a weekly or biweekly schedule.

More than twice as much biomass was produced in all components except inflorescences in 1991 compared to 1992. These results can be explained by the difference in reproductive status between the 2 years, vegetative in 1991 and reproductive in 1992. When clipping was begun in 1991, number of tillers/plants averaged 23 and increased to 26 by studies end. In 1992, number of tillers/control plants increased from 7 to 8 during the study while they increased from 9 to 26 for the clipped plants during the same period. Thus, plants in the vegetative state in 1991 continued to produce new leaves; whereas, plants in 1992 responded to clipping by producing new tillers. Tiller production takes longer than leaf production and should, therefore, result in lower yields.

Conclusions

The results of this series of studies are important because they describe characteristics of Japanese brome that indicate it may be a component of Northern Great Plains rangelands for years to come. Germination studies showed temperature is likely not a limiting factor for fall germination of Japanese brome seed that is disseminated in summer or fall. If soil moisture is adequate, high levels of germination will often occur during the initial fall period. This results in a large population of Japanese brome seedlings which can survive over winter and commence growth early the following spring.

As with downy brome, complete germination of all Japanese brome seeds in 1 season is rare. Seeds which are not disseminated or do not germinate in fall, go through the winter as seeds and potentially enter a state of secondary dormancy. Only a small proportion may germinate before the next fall.

The germination process appears to shift in response to moisture and temperature from one in which most seeds germinate at once to one in which seed germination is delayed with only a few seeds germinating at any one time. These processes result in a carry over of a large number of viable seeds from year to year, complicating control of Japanese brome through conventional means. Japanese brome seed germination characteristics also aid its future invasion and perpetuation on rangelands in the Northern Great Plains.

Total standing crop was reduced consistently and significantly both years by removal of Japanese brome at both competition study sites. However, Japanese brome reduced production of western wheatgrass only when the supply of moisture was insufficient to meet the demands of both species. Thus, Japanese brome appears to be adding to the total forage base, and we can expect a short-term decline in total forage production when it is absent.

Although not examined in this study, Japanese brome competition may have a cumulative effect on western wheatgrass plants when encountered during a period of several years. In addition, western wheatgrass plants may respond to competition differently with or without clipping or grazing. To answer these questions will require additional research.

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

Recent Publications

Haferkamp, M.R., M.G. Karl, and M.D. MacNeil. 1993. Influence of location, storage, temperature, and light on germination of Japanese brome seed. J. Range Manage. (In press).

Regrowth of the RS-Hybrid with Varying Moisture Conditions

M.R. Haferkamp, D.C. Adams, and P.O. Currie

Introduction

RS-2 is a hybrid of bluebunch wheatgrass x quackgrass developed by the USDA-ARS Crops Research Laboratory, Logan, Utah. It is moderately rhizomatous and is an earlier generation of the recently released `Newhy'. RS-2 has been grown successfully since 1981 under irrigation at Fort Keogh LARRL, Miles City, Montana, where it is adapted to saline soils and is readily grazed by livestock.

The objective of this research was to examine the impact of irrigation, fertilization, and defoliation on growth and water relations in RS-2. The findings can be utilized to develop efficient systems for managing this hybrid in the Northern Great Plains.

Methods

In 1990 and 1991, studies were conducted on 2 sites under the center pivot irrigation system. The study compared mowing to a 4" stubble in June and July and again in October versus mowing in July, August, and October; fertilizing at 0 lbs N/ac versus a single spring application of 89 lbs N/ac; and full irrigation on one set of 89 lbs N/ac plots versus two-thirds irrigation. Standing crop data are presented in this report.

Results

Precipitation + irrigation totaled 1.1" in May and 3.9" in June 1990, while precipitation alone totaled 4.5" in May and 2.6" in June 1991. The grass standing crop harvested from the plots was different in 1990 and 1991. In 1990, 575 + 1029 + 865 lbs/ac = 2469 lbs/ac were harvested with the June-July-October treatment, and 2145 + 606 + 421 = 3170 lbs/ac were harvested with the July-August-October treatment. In contrast, in 1991, 2007 + 86 + 981 = 3074 lbs/ac were harvested with the June-July-October treatment, and 1875 + 133 + 516 = 2524 lbs/ac were harvested with the July-August-October treatment.

This small portion of the overall data set suggests differences in regrowth occurred during the second harvest during these 2 years. In 1990, 42% of the total was harvested in July and 19% in August, while in 1991, 3% was harvested in July and 5% in August.

Conclusions

These results are not conclusive, but they suggest one should be concerned with potential regrowth from this grass when growing on irrigated pastures in the Northern Great Plains. In those years, in which a large amount of biomass is removed in early summer, regrowth may be slight for the next month or so. Producers using this grass need to be aware of this potential lack of forage, and be prepared to utilize alternative forage in these situations.

Recent Publications

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

Rangeland Seed Banks

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

Introduction

The health of Northern Great Plains (NGP) rangelands depends on reproduction of the plant species and how effectively the plants reproduce after disturbances (e.g., drought and livestock grazing). A seed bank, which represents the seed stored in the soil and on the soil surface, is important to reproduction of most plants. Learning about seed banks can help us better predict how and why rangelands respond to disturbances the way they do, and additionally, assist us in the development of management tactics that exploit the positive aspects of seed banks. We are quantifying the seed bank of a native NGP rangeland for these purposes.

Study Site and Methods

From visual observation, the study site was dominated by western wheatgrass, blue grama, Japanese brome, needle-and-thread, and plains prickly pear. Cattle did not graze the site during the study nor for 6 years previous to the study, but grazing by native herbivores was permitted.

During the study, we quantified: 1) aboveground production (weight of plant material); 2) seed held aloft (non-disseminated seed); 3) plant seedlings; 4) disseminated seed residing in the litter (dead plant material on the soil surface); and 5) disseminated seed residing in the soil. We vacuumed the litter to collect the seed therein and cored the soil to a depth of about 1.5 in to collect the seed therein. We placed the litter and soil in growth chambers in which light and temperature could be controlled. We counted and identified to species the seedlings which emerged from the litter and soil, and these counts characterized the seed bank.

Results

Aboveground production. Blue grama was the dominant species. Averaged across the collection dates, blue grama contributed 37% of the aboveground plant material, western wheatgrass 23%, and Japanese brome 12%. Contributions from buffalograss, Sandberg's bluegrass, and needle-and-thread were consistently small.

Non-disseminated seeds. Seed production was dominated by blue grama and Japanese brome. These 2 species contributed 81% of all the non-disseminated seed held aloft in the summer and almost 80% in mid winter. Although about 30 species were found on the site, only about 20% of them contributed much seed. Ample seed of blue grama and Sandberg's bluegrass, 2 native perennial (long-lived) grasses, appeared to have been produced. Seed production of western wheatgrass, buffalograss, needle-and-thread, and tumblegrass (other perennial grasses) was almost negligible.

Plant seedlings. Most plant seedlings observed on the study site emerged in early fall of 1991 and late summer of 1992 (Fig. 1), after rainfall events. Seedling numbers were overwhelmingly (more than 95% on any date) dominated by annual (short-lived) plants, especially Japanese brome, sixweeks fescue, woolly indianwheat, and fairy candelabra. Perennial grass seedlings were few and the most notable were blue grama, Sandberg's bluegrass, and needle-and-thread. We only saw 1 seedling of western wheatgrass and none for buffalograss. The total number of seedlings observed varied drastically, being much higher in the fall of 1991 than fall of 1992.

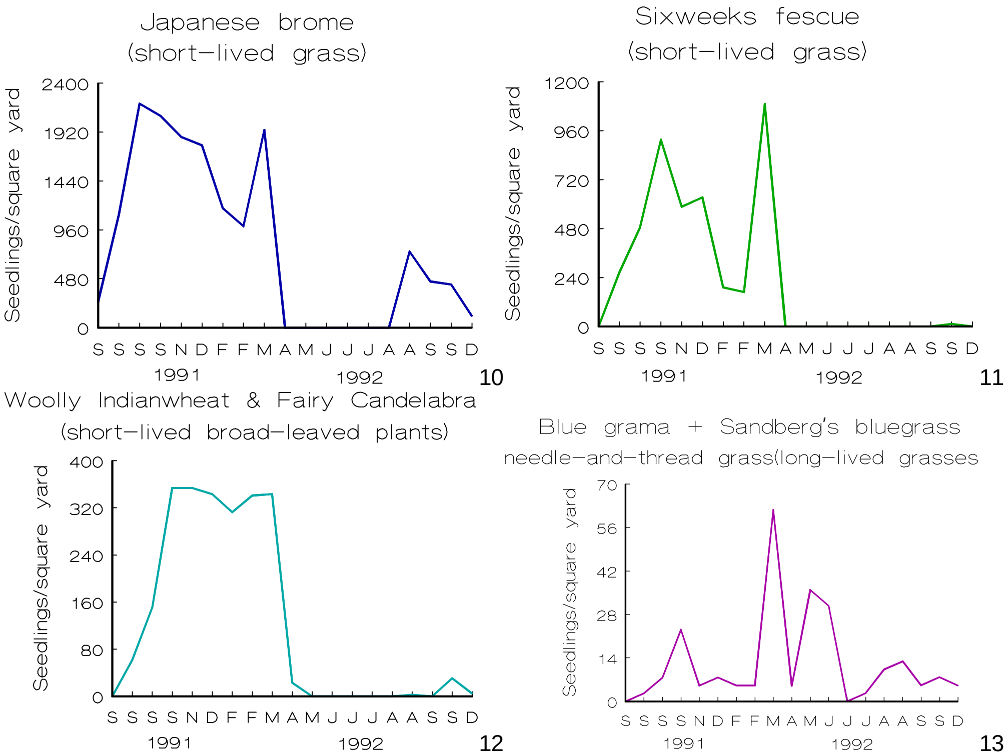

Figure 1. Plant seedlings observed on the study site from late summer 1991 through late fall 1992. Numbers presented represent numbers of seedlings found per square meter.

Seed in the litter. Seed in the litter was dominated by Japanese brome and sixweeks fescue (Fig. 2). At any date we sampled, these 2 species contributed between 50 and 85%. Of the perennial grasses, blue grama and Sandberg's bluegrass contributed appreciably, and western wheatgrass, buffalograss, needle-and-thread, and tumblegrass did not. From early winter through late spring the contribution of blue grama plus Sandberg's bluegrass was greater than 30%.

Seed in the soil. More plant species contributed seed to the soil cores (Fig. 3) compared with the litter (Fig. 2), and Japanese brome and sixweeks fescue did not dominate the soil core portion to the extent they dominated the litter. Similar to the litter, of the perennial grasses, only blue grama and Sandberg's bluegrass contributed sizeable numbers of seed to the soil. We detected a few emergent seedlings of western wheatgrass, needle-and-thread, and tumblegrass from the soil cores; whereas, none were found for buffalograss.

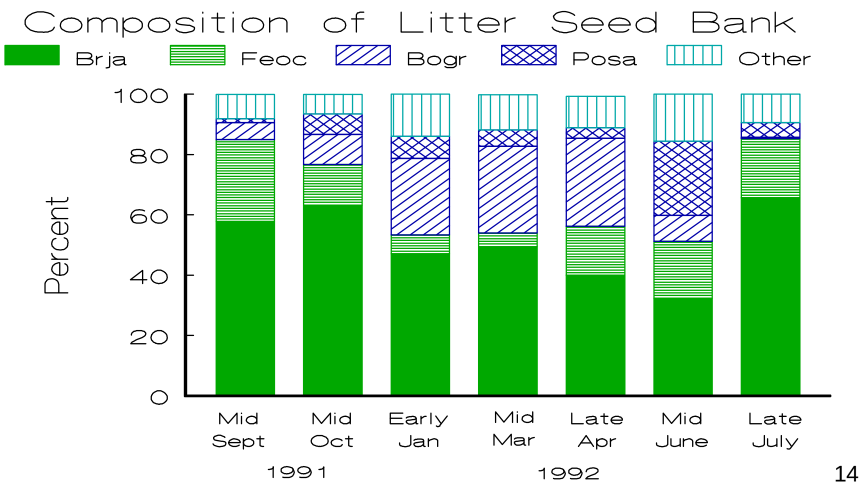

Figure 2. Percent contribution of the plant species that contributed to the litter seed bank from late summer 1991 through mid summer 1992. Brja = Japanese brome; Feco = Sixweeks fescue; Bogr = Blue grama; and Posa = Sandberg's bluegrass.

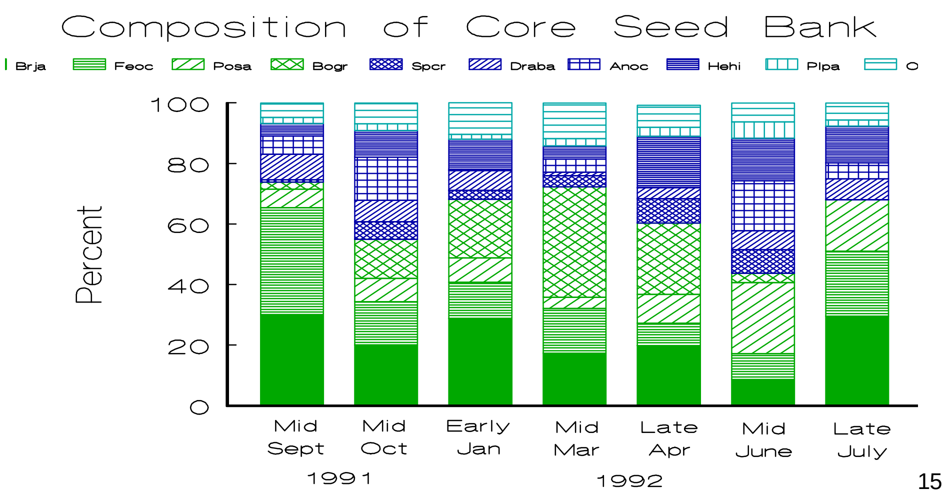

Figure 3. Percent contribution of the plant species that contributed to the soil seed bank from late summer 1991 through mid summer 1992. Brja = Japanese brome; Feco = Sixweeks fescue; Posa = Sandberg's bluegrass; Bogr = Blue grama; Spcr = Sand dropseed; Drab = White whittowort; Anoc = Fairy candelabra; Hehi = Rough false pennyroyal; and Plpa = Wooly indianwheat.

Conclusions

From a study of the seed bank of a native rangeland site, the following are important conclusions:

1) Blue grama and western wheatgrass were the 2 top contributors to aboveground production. Blue grama and Japanese brome were the 2 dominant seed producing

species based on counts of non-disseminated seeds. Although western wheatgrass contributed substantially to aboveground production, it and buffalograss, needle-and-thread, and tumblegrass produced few seeds;

2) Plant seedlings on the study site were overwhelmingly (greater than 95%) dominated by annual, short-lived plants especially Japanese brome, sixweeks fescue, woolly indianwheat, and fairy candelabra;

3) Annual plants, especially Japanese brome and sixweeks fescue, dominated the seed bank in the litter (dead plant material on the soil surface) but less so the soil seed bank. Of the perennial plants, only blue grama and Sandberg's bluegrass contributed appreciable seed to the litter and soil seed banks; and

4) We believe there may be cause for concern for the "health", as we know it, of rangelands in the Northern Great Plains because: a) reproductively, Japanese brome, a non-native plant species, clearly becomes an important species on these rangelands once it establishes itself; b) reproductively, the perennial plant species are not apparently very important on these rangelands because very few seedlings were seen; and c) except for blue grama and Sandberg's bluegrass, the perennial plants present were found to produce few seeds thereby contributing little to the seed bank of these rangelands.

Reducing the Impact of Drought on Northern Great Plains Rangelands

R.K. Heitschmidt

Introduction

The 2 major problems encountered in the management of most rangeland ecosystems lies in: 1) inability to anticipate droughts (i.e., we know when we've been through a drought but we didn't know when it was coming); and 2) our lack of understanding of what the long-term effects of drought are on the rangeland resource. The objective of this study is to elucidate how rangeland managers might modify their management schemes to better cope with drought.

Methods

An automated rainout shelter is currently being constructed to provide researchers the opportunity to create a "drought year" at their will. The shelter is basically a "building roof on wheels" that automatically moves across a set of plots when it begins to rain.

The plots are 15' by 30' non-weighing lysimeters. Lysimeters are isolated blocks of soil. Our lysimeters were built by trenching around the perimeter of each lysimeter to a depth of about 7' and then filling the trench with the liquid foam insulation used to insulate standing walls of completed buildings. We then built a wooden foundation over the top of these filled trenches to prevent surface water from running onto or off the plots.

Utilizing this rather elaborate design, we are able to evaluate the effects of 3 grazing/drought treatments on the quantity and quality of forage produced, water quality and yield, seed bank dynamics, and plant physiological processes. The 2-year treatments are: 1) graze year 1 with drought, graze year 2 without drought; 2) graze year 1 with drought, rest year 2 without drought; 3) rest year 1 with drought, rest year 2 without drought; 4) graze year 1 without drought, graze year 2 without drought; 5) graze year 1 without drought, rest year 2 without drought; and 6) rest year 1 without drought, rest year 2 without drought.

Conclusions

The design of this study is such that we hope to provide rancher clientele with better insight as to how to better cope with drought through the use of new and innovative grazing tactics.