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Agricultural Research at the Reed Ranch Substation: A Progress Report

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AGRICULTURAL RESEARCH AT THE

REED RANCH substation

A progress report

AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE
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Contents

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Agricultural Research

AT THE REED RANCH FIELD STATION

Reed Ranch is located in Lyman County about midway between Pierre and Presho. It consists of 2,160 acres used for grazing and hay production. This ranch has been used for nearly 20 years as a field laboratory for selenium research.

On November 16, 1936, an agreement between the South Dakota State College Agricultural Experiment Station and the South Central South Dakota Land Adjustment Project of the Resettlement Administration outlined a program of cooperative research dealing with selenium poisoning. The program was initiated during 1937 and has continued since.

As governmental organization has changed over the intervening years, the cooperating agency representing the Federal Government has also changed from time to time. The present cooperating agency is the U. S. Forest Service. The agreement now in effect covers the period from 1954 to 1964, and renewal beyond that period is anticipated.

The present long-range policy has permitted the Experiment Station to make much needed physical improvements that have made the work at Reed Ranch easier and more efficient since 1953. The facilities for handling cattle have been rebuilt, living facilities modernized, and some additional fencing has been done. A shelterbelt has been planted north of the farmstead and 80 acres of native hayland are being replanted to alfalfa.

The purpose of this publication is to acquaint citizens of South Dakota with research at Reed Ranch. It summarizes past and present experimentation and outlines plans for the future. This ranch is unique as a substation in that it was provided and is maintained to obtain information concerning chronic selenium poisoning or "alkali disease" in range cattle.

Figure 1. Superintendent James Rahn and his family.

Selenium Poisoning

Since most of the work at Reed Ranch concerns selenium poisoning, it may be well to relate the history and nature of this poisoning. In 1856 an army surgeon stationed at Fort Randall, Territory of Nebraska (now in South Dakota), wrote a report describing a curious malady in horses at that station. The cause was unknown, but the symptoms were later observed in livestock by settlers in this and other areas. It was believed by many at that time that "alkali" waters, seeps, or spots in the soil somehow caused the symptoms. The term, "alkali disease," therefore, came into common usage.

Research early in this century gave results which strongly indi-

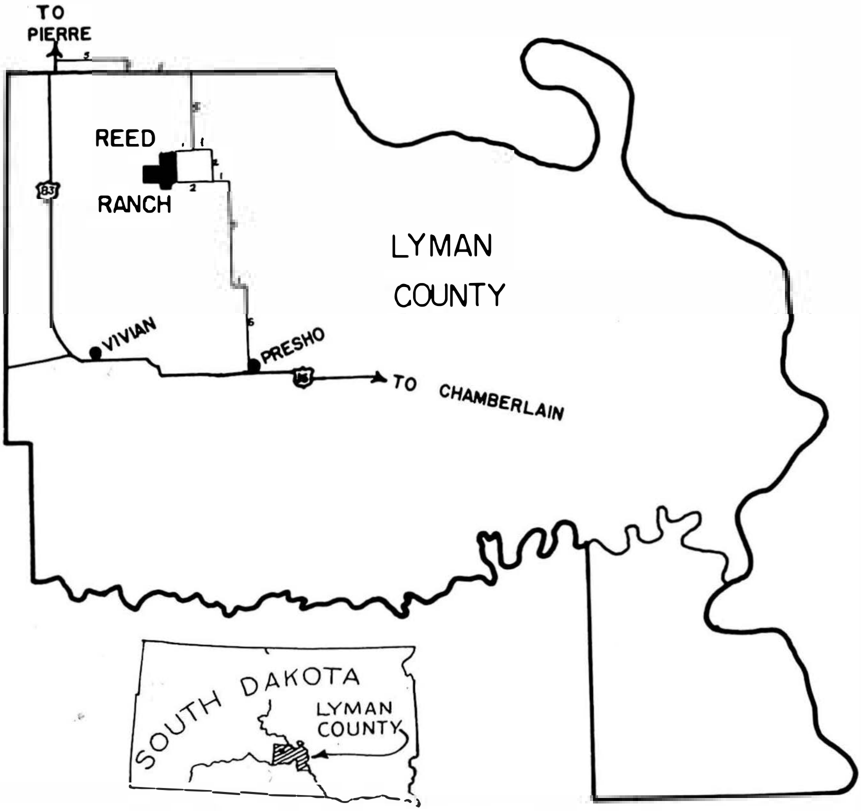


Figure 2. Reed Ranch is located in the northwest corner of Lyman County in central South Dakota. Visitors are always welcome.

cated that alkali was not the cause of the disease. However, several attempts to determine the cause were not successful. In the early 1930's plant analyses and animal feeding studies made largely at the South Dakota Agricultural Experiment Station showed that the symptoms observed were a manifestation of chronic poisoning by selenium.

Selenium is an element. It had been known to be toxic for a number of years prior to its implication in "alkali disease," but no one suspected it of being a naturally occurring poison. Now we know that it is present in certain soils and that plants that grow in these soils absorb it. Animals that eat these plants (containing over 5 parts per million of selenium) over a period of weeks or months become slowly poisoned and exhibit the symptoms of "alkali disease."

Certain plants absorb large amounts of selenium, and if these are eaten they may cause acute selenium poisoning. This differs in the symptoms it causes from the chronic or "alkali disease" type of poisoning. Its occurrence in South Dakota is apparently rare, however, and it will not be discussed here.

Chronic selenium poisoning can affect most farm animals. The symptoms generally observed are emaciation, lack of vigor, stiffness of the joints (often with swelling), rough hair coat, loss of long hair, and cracking of the hoofs. Anemia is common, there is a loss of appetite, and reproduction is affected.

In horses, the loss of hair from the mane and tail is one of the first symptoms. The term "bob-tailed disease" has therefore often been used in connection with the poisoning in these animals.

Horses, cattle, and swine all exhibit joint stiffness, which is probably connected with erosion of the joints of the long bones. They also show the very typical hoof symptoms. These began with an inflammation and soreness at the junction of the hoof with the skin. Following this, a circular crack develops in the hoof. As the hoof continues to grow the crack moves downward, and finally the hoof beyond it may be sloughed. Sometimes, however, it is not, and deformed hoofs of a variety of shapes may result, especially in cattle. Cattle often lose the hair from the switch of their tail and swine may lose the short hair from the body.

Figure 3. Bull with selenium poisoning. Note his elongated hoofs and the area on his knees worn bare from moving about on them to graze. All the long hair of this bull's tail had dropped off.

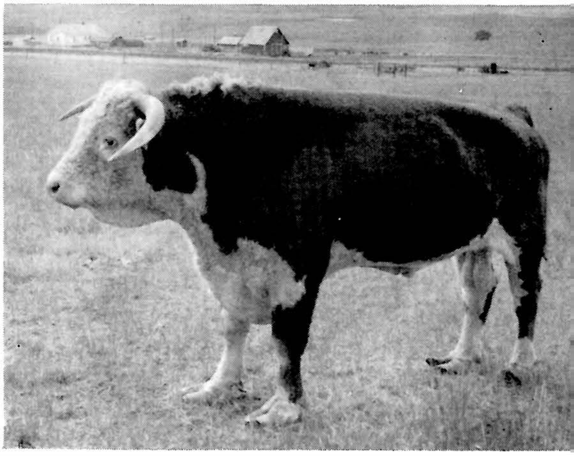


Figure 4. Approximate locations of some of the farms and ranches where selenium poisoning symptoms have been observed. This map shows only a part of all cases observed, but illustrates the general areas where selenium poisoning occurs in the state.

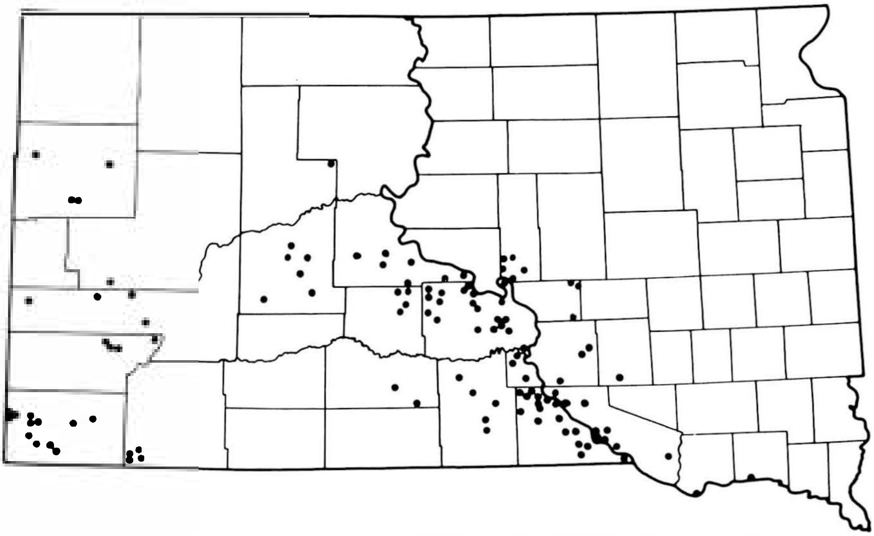


Figure 5. Selenium reduces hatchability of eggs as a result of malformations of embryos.

Symptoms of chronic selenium poisoning in sheep have not been well described, probably because they are not often observed. Malformations in new-born lambs may be an important manifestation of the toxicity, however.

The most noted effect of selenium in poultry is the greatly reduced hatchability of eggs from hens on seleniferous rations. The selenium does not seem to seriously reduce the fertility of the eggs, but it causes the development of malformed embryos which either die before hatching time or are unable to break through the shells. Chicks that do hatch often have a "greased" appearence.

Considering the farm animals that are affected by selenium poisoning, practical control measures for cattle on seleniferous range offer

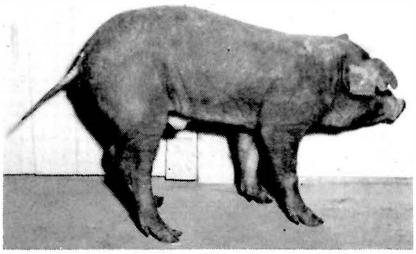


Figure 6. Pig with selenium poisoning. Note poor condition, loss of hair, and cracks at junction of hoof and skin.

the greatest challenge. It is not possible to estimate the animal loss resulting from this toxic element because most of the damage is not reported and probably not recognized. However, cases of selenium poisoning have been observed in 21 counties of the state and in these areas improper gains, possible decreased calf crops, inserviceability of bulls, and the other symptoms discussed all contribute to decreased income.

Measures for preventing these losses are not easy to establish because they must be tailored to fit management practices for range animals. However, laboratory experimentation has given several possibilities for control of the poisoning, and Reed Ranch offers the opportunity to try these on naturally seleniferous range under normal ranch conditions.

The Weather and the Land

Reed Ranch lies in Sec. 35, T. 108 N., R. 78 W., Sec. 2 and 3, and 240 acres of Sec. 11, T. 107 N., R 78 W., in northwest Lyman county. The ranch has considerable relief, the highest point being a hilltop at about the middle of the north line of Sec. 3., T. 107 N., R. 78 W. and the lowest in the northeast corner of Sec. 35, T. 108 N., R. 78 W. The maximum relief is about 240 feet.

Three members of the Pierre formation are represented on the ranch as evidenced by natural outcrops, outcrops in road grades, animal burrows, borings, and soils. The lower 25 feet are moderately to highly calcareous shale and chalky shale, which weather buff to brown. These beds break down on weathering to chalky clays and gumbo clays. The position and characteristics of these beds place them in the upper part of the Virgin Creek member of the Pierre formation.

Above the Virgin Creek member lie beds 130 feet thick, which are classified as the Mobridge member of the Pierre formation. The beds of the Mobridge grade upward from chalk to chalky shale and then into calcareous shale; they weather from nearly white through buff and yellow to light brown.

Overlying the Mobridge member are beds of brown to gray calcareous shale. These uppermost beds, which are about 50 feet thick, occupy the position of the Elk Butte member of the Pierre formation. The beds of the Pierre formation lie nearly horizontal in this area.

Alluvium has accumulated along the valley bottoms and reaches a

Figure 7. Reed Ranch—steeply rolling, almost treeless, good grassland.

thickness of 15 feet or more in the larger valleys. Slope mantle and soil cover most of the surface.

Soils formed from these members of the Pierre formation are classified in the Promise and Pierre series. These are Chestnut soils which have developed under mixed short and tall-grass vegetation in a subhumid region.

The climatic environment of the ranch is of the continental type, subject to extremes of summer heat and winter cold, together with rapid fluctuations in temperature. The average temperature for January is about 17° F. and for July about 75° F. Precipitation averages 17.5 inches per year with about two-thirds of it falling, chiefly as rain, from April through August. The frost-free growing season is approximately 141 days.

The climate being characteristically continental and subhumid, extended periods of drought are frequent. This markedly affects the relative proportions of the various native grasses in the vegetative cover and particularly allows for the invasion of the sod by certain weedy species. Generally, the grass cover consists of blue grama, buffalo grass, and western wheatgrass sods, with green needle, needle-and-thread, sideoats grama, cheat, and little bluestem grass intermixed.

Selenium in Soils

Even before selenium was found to be the cause of "alkali disease," it was recognized that there was some correlation between the occurrence of the disease and the soils of the area. After selenium was established as the cause, it became important to determine why certain soils contained the elements in amounts that made vegetation toxic while others did not. A study of the geology of the state showed why.

Geological Origin

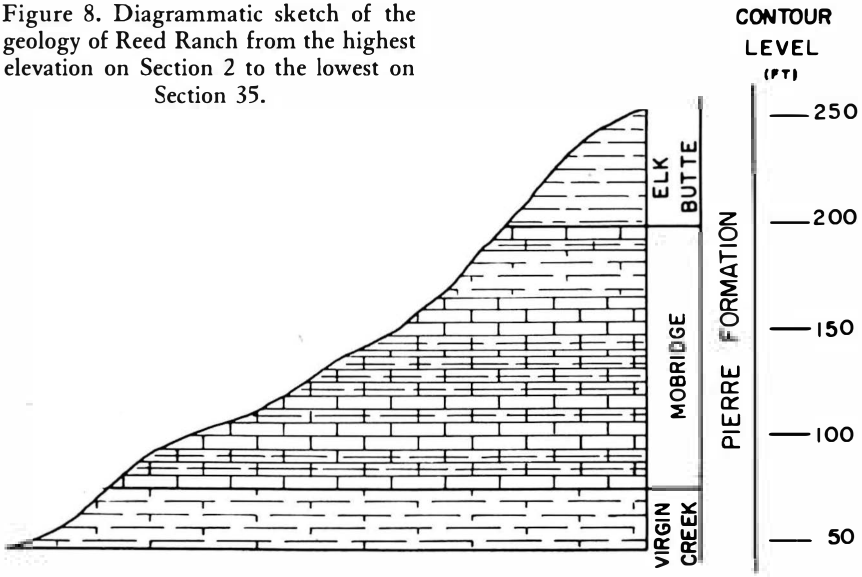
At one time the Great Plains was covered by a shallow sea. During this time sediments were deposited in the sea and these sediments gave rise to many different geological formations, lying in layers one upon another. Some of these sediments contained selenium in relatively high concentrations while others contained but little, but where it came from has not been established. Thus, certain geological formations are relatively seleniferous while others are not.

After the seas subsided a period of erosion began and is still in progress. Depending upon the nature and extent of erosion, different formations have been exposed in certain areas and have weathered to soils. Where formations containing selenium in relatively high amounts have weathered to soils, the soils are seleniferous. In South Dakota, the formations likely to weather to seleniferous soils are the following: Niobrara, Mobridge member of the Pierre (especially in the vicinity of the Missouri River), Sharon Springs member of the Pierre, Upper Virgin Creek member of the Pierre (especially near the Missouri River), and occasionally Greenhorn. These formations seldom appear in eastern South Dakota because they have been covered by glacial till. Since Reed Ranch soils have been weathered almost entirely from the Mobridge and upper Virgin Creek members of the Pierre formation, they are in large part seleniferous. There have been many forces at play, however, in the development of these soils, so that while seleniferous areas may be mapped in a general way from a knowledge of the geology, detailed mapping is impossible.

Available Selenium in Soil

After it was discovered that selenium caused "alkali disease," it

Figure 8. Diagrammatic sketch of the geology of Reed Ranch from the highest elevation on Section 2 to the lowest on Section 35.



seemed logical that soil analysis would be a valuable tool in mapping out seleniferous areas. However, it was soon found that an analysis of the surface soil gave no indication of how much selenium was contained by plants growing in the soil. One of the first experiments carried on at Reed Ranch showed further that the selenium content of the soil to a depth of 3 feet could not be used as a guide in determining how much selenium would be absorbed by plants growing in the soil. The data in table 1 illustrate this.

In view of these results, it appeared that only a part of the selenium in soils was available to plants, so attempts were made to develop a method for measuring its availability. In greenhouse experiments it was found that the amount of the element extracted from a soil by water gave a fairly good indication of the amount plants would absorb from the soil. Extraction with acid or alkali gave much less reliable results.

The water-soluble selenium content of the soil at several Reed Ranch locations was then compared with the selenium content of western wheatgrass growing in the soils. The data in table 2 illustrate that there was poor correlation between the value for the 0-12-inch depth of soil and for the plant. The average value for the 3-foot depth was much better in this respect, but still failed to be a highly accurate measure of available selenium. Another experiment, carried out in the greenhouse with soils from the three depths at location 7, verified this conclusion (table 3).

From these studies it was concluded that the usual procedure of examining the soil to plow depth for available nutrients would not be satisfactory in the case of selenium. Obviously, much of the selenium in the plants was coming from greater depths. Analysis of the soil to a 3-foot depth for soluble selenium appeared somewhat more satisfactory, but even this would not give the reliable results considered necessary for accurate detailed mapping of the land as to its potential for producing seleniferous plants.

Table 1. Selenium Content of Soils and Western Wheatgrass Growing in These Soils

Plot No.	Depth of Soil Sample (in.)	Selenium Content (p.p.m., air-dry basis) Soil	Western Wheatgrass
1	0-12	1.5	24
	12-24	3.6	
	24-36	5.0	
2	0-12	3.9	1
	12-24	3.5	
	24-36	3.9	
3	0-12	1.6	4
	12-24	1.5	
	24-36	2.4	
4	0-12	3.8	3
	12-24	3.7	
	24-36	4.9	
5	0-12	2.1	7
	12-24	3.8	
	24-36	3.3	

*Parts per million.

Table 2. Water-Soluble Selenium and Sulfur Content of Soil and the Selenium Content of Western Wheatgrass Growing in the Soil

Location No.	Depth of Soil Sample (in.)	Water Soluble Content of Soil (p.p.m., air-dry basis)		Selenium Content of Western Wheatgrass (p.p.m., air-dry basis)
		Selenium	Sulfur	
6	0-12	0.1	—*	18
	12-24	2.8	—	
	24-36	0.6	—	
		Av. 1.2		
7	0-12	0.4	345	79
	12-24	5.0	2,910	
	24-36	10.9	5,770	
		Av. 5.4		
8	0-12	1.4	375	8
	12-24	0.5	360	
	24-36	2.7	5,100	
		Av. 1.5		
14	0-12	0.9	450	35
	12-24	17.6	4,870	
	24-36	19.0	6,450	
		Av. 12.5		
21	0-12	0.1	—	2
	12-24	0.1	—	
	24-36	0.1	—	
		Av. 0.1		

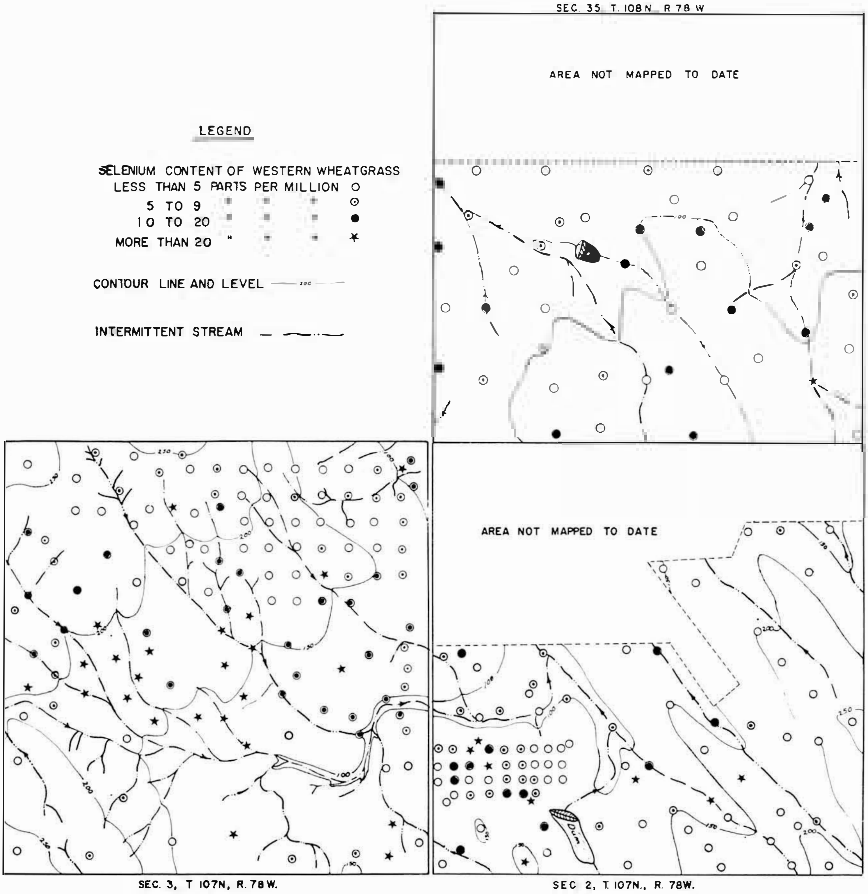
*No data available.

Plant Analysis in Mapping Seleniferous Soils

In view of the results just discussed, is was felt that the analysis of plants would be necessary in any detailed mapping program. Many factors of variability must be considered here too, and these will be discussed later. However, by analyzing the same kind of plant at the same stage of growth in all instances, most of the variability can be eliminated, Therefore, a program of mapping Reed Ranch based on plant analysis was undertaken to determine what difficulties might be encountered and whether detailed mapping would be feasible.

Western wheatgrass was collected from a number of locations over a period of several years. Dates of sampling varied between July 1-15. The plants were dried at 75° C. and analyzed for selenium. The data obtained to date are shown in figure 9.

Figure 9. Selenium content of western wheatgrass sampled in early July over a period of years at various locations.



From what information is shown in figure 9 certain conclusions seem obvious. In the first place, contour maps are of limited assistance in the detailed mapping of seleniferous land. The highly seleniferous areas at Reed Ranch are intermingled with areas of vegetation of very low selenium content lying at similar elevations.

At the highest elevations, (at about the 250-foot contour line) the soils are derived from the nonseleniferous Elk Butte member of the Pierre formation, and they produce nonseleniferous plants. During the soil forming process some of this Elk Butte member has been washed or has slumped to lower levels, and this in part accounts for vegetation of low selenium content at these levels.

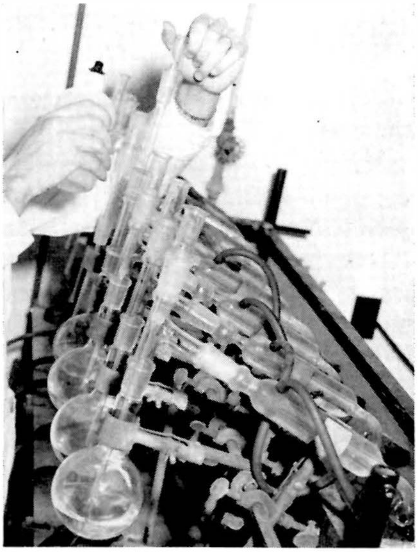
Table 3. Selenium Content of Wheat Plants Grown in the Greenhouse on Soils of Different Soluble Selenium Contents

Soil Description	Selenium Content (p.p.m., air-dry basis) Soils Total	Soils Water-Soluble	Wheat Plants
Location 7, 0-12 in. depth	4.3	0.4	4
Location 7, 12-24 in. depth	15.8	5.0	20
Location 7, 24-36 in. depth	29.0	10.9	16

Other factors, however, are no doubt active in this respect also, the depth of leaching of the selenium probably being one important factor.

The great variations in the selenium content of western wheatgrass northwest of the dam on Section 2 as well as at several other locations indicates how difficult detailed mapping is. It requires an intensive sampling and analyzing program to give enough information to satisfy the needs. Under most conditions such intensive sampling and analysis would not be practicable because of cost.

Figure 10. The selenium analysis requires skill and takes much time.



Attempting to isolate the most seleniferous portions of the range from use will usually not be, therefore, a valuable control measure, so other methods of preventing losses from the poisoning must be developed. However, the information obtained in the course of this study is of great value in the management of future experimental work at Reed Ranch, since it allows for the fencing of areas to give pastures of varying degrees of selenium poisoning potential.

Sea Salt Studies

Other work has indicated that applications of sea salt to soil depresses selenium uptake by certain crop plants. Similiar studies were made on a plot of wheat at Reed Ranch and also in the greenhouse with the same soil.

Applications of the salt were made at rates of 1, 2, and 3 tons per acre and in addition certain plots were treated with specific chemical compounds in the proportions in which they occur in the sea salt. The 3 tons per acre level was sufficiently salty so that the wheat did not grow beyond the seedling stage.

A slight decrease in selenium uptake by the wheat plants was

Figure 11. A part of the plot used in sea salt investigations. Bare area at left center represents effect of 3-ton level of application.

found for the lower levels of salt application. Using artificially selenized soils and applications of pure chemical salts, it was found that some of the effect could be attributed to sulfate in the sea salt, and in addition, that the sodium chloride present in sea salt could suppress part of the uptake of selenite selenium. The application of sea salt, sulfates, or chlorides does not, however, appear to be of any practical importance as a selenium control measure.

Selenium in Plants

Selenium Content of Various Plants

Various kinds of plants have been found to differ markedly in their ability to accumulate selenium, though grown on the same soil within short distances of each other and under the same climatic conditions. Certain plants have been found to accumulate large amounts of selenium from seleniferous soils. These have been referred to as selenium "converters" or accumulators. At the same time, common crop plants and native grasses absorb relatively small, though sometimes toxic, amounts of selenium from these soils.

Among the selenium-accumulating plants found at Reed Ranch are *Astragalus racemosus*, white aster (*Aster multiflorus*), broom snakeweed (*Guterriezia sarothrae*), and gumweed (*Grindelia squarrosa*). Of these plants *Astragalus racemosus* usually contains the most selenium and it is often referred to as a selenium-indicator plant, due to its apparent requirement for this element in normal growth. Other selenium-indicator plants, princes plume (Stanleya bipinnata), woody asters (*Xylorrhiza* sp.), and golddenweeds (*Oonopsis* sp.), are not common to the Reed Ranch.

Whereas the selenium-accumulating plants will range from 10 p.p.m. to over 500 p.p.m. in selenium content at Reed Ranch, the native grasses (western wheat, green needle, buffalo, blue grama, sideoat grama, needle-and-thread) and the weed plants (sunflower, pigweed, Russian thistle, snow-on-the-mountain, goldenrod, prairie pink, purple coneflower, wooly loco) usually contain less than 20 p.p.m. of selenium. However, localized areas at Reed Ranch have produced western wheatgrass containing almost 80 p.p.m.

Two small plots at Reed Ranch (one of wheat and another of *Astragalus racemosus*) have been used to grow plants containing radioactive sulfur and selenium. Radioactive sulfur (as sulfate) and radioactive selenium (as selenate) were applied to both plots. The purpose of these studies was to obtain plants with radioactive sulfur or selenium incorporated into the various compounds in the plant that ordinarily contain sulfur or selenium. Since the amount of these elements present is not always adequate for determination by the usual methods of chemical analyses, radioactivity would serve as a tag which would aid in identifying these compounds as they were separated from the plant material.

These studies did not confirm previous indications that selenium might be incorporated into protein in compounds similar to those containing sulfur. Radioactivity was found in other compounds, but attempts to isolate these compounds in sufficient quantities for identification have been unsuccessful.

Factors Affecting the Selenium Content of Range Plants

As has been noted, the selenium content of one kind of plant may vary widely from that of another.

This variablitiy in selenium uptake exists within a group of similar plants, such as the native grasses. Western wheatgrass and green needle grass generally have the highest selenium contents, with wheatgrass averaging 1.5 times as much selenium as green needle grass.

Analyses of soils and of many different species of plants have shown

Figure 12. Sampling grass for analysis.

that the arsenic content of the soil samples ranged from 7 to 18 p.p.m. and the selenium content from 1.2 to 5.0 p.p.m. None of the vegetation growing on these soils contained more than 4.3 p.p.m. arsenic, but some of the plants contained as much as 267 p.p.m. of selenium. Thus, plants differ not only in selenium uptake, but also they accumulate less arsenic, though the latter is present in the soil in larger amounts than selenium. To what extent arsenic as a plant constituent serves as an antagonist of selenium toxicity is not known.

Usually selenium content is highest in young plants growing on seleniferous soils. Thereafter, the selenium content of these plants decreases slowly until the plant has reached maturity, when the decrease is quite marked. An example of this trend is shown in table 4. The rapid decrease in selenium content of western wheatgrass, green needle grass, and sunflowers is probably the result of losses of selenium in volatile forms, the shedding of seeds, and the loss of leaves. Similar results have been obtained for needle-and-thread grass, blue gramma grass, and sideoat gramma grass. Gumweed is unlike the other plants sampled, increasing steadily in selenium content throughout the late stages of growth. Certain other plants have been found to be much like gumweed in this respect.

In field studies made in 1938 it was shown that plant associations had an effect on the selenium content of grass, particularly when selenium-accumulating plants were involved. Western wheatgrass sampled from within a patch of white astors contained 36 p.p.m. of selenium, while samples of the same grass taken 20 feet outside the patch of astors contained only 15 p.p.m. Other workers have obtained similar results.

Variations in land elevation (topographic) have no direct relationship to the selenium content of the vegetation, except that due to the particular geological formations present. As has been mentioned, certain geological formations contain more selenium than others. Where changes in elevation expose these seleniferous beds and soils develop on them, it is probable that the plants will contain selenium.

It has been shown that the selenium content of plants is not strictly related to the total selenium content of the soils on which they are grown. Some fairly seleniferous soils will support plants containing negligible amounts of selenium. As noted in an earlier discussion and illustrated in table 2, the water-

Table 4. Effect of Maturation on the Selenium Content of Plants. (Samples Collected in 1939 and Data Expressed as p.p.m. of Selenium.)

Sampling Date	Western Wheatgrass	Green Needlegrass	Sunflowers	Gumweed
June 12	12.6	9.7	26.0	76.5
June 22	11.0	10.7	20.5	153.0
July 6	9.2	9.5	23.0	217.0
July 22	8.6	10.0	15.0	299.0
August 16	5.8	5.2	7.6	293.0
September 19	3.6	3.7	3.0	*

*Sample not collected.

extractable selenium, particularly from soil depths at the second and third foot, seems to be an important factor bearing on the selenium content of the plants. The water-soluble selenium in the soils at Reed Ranch has been found to consist mainly of inorganic selenium, and this fraction is almost entirely selenate selenium. The selenite selenium (ordinarily water-soluble) seems to be bound to the soil in some way, perhaps to the iron compounds that are present. Of the water-soluble forms, selenite is therefore absorbed by plants in lesser amounts than selenate or organic selenium, while selenium in the form of iron selenide appears to be available only to the *Astragalus* and *Stanleya* plants.

Table 2 also shows how sulfur, as sulfate compounds, accumulates in soil depths at the second and third foot. Other work has indicated that sulfate depresses the absorption of selenate selenium by plants. In field studies at Reed Ranch, sulfur applications were found to be without effect on the selenium content of the plants. The fact that sulfate is already present in amounts greater than could be practically applied probably means that the effect of sulfate on selenium uptake is already reflected in the selenium content of the plants and that further additions will have only a small effect. This is a way of saying that the selenium content of plants in seleniferous areas would very likely be much higher, were it not for the high sulfate content of these soils.

The effect of climate, particularly the amount of rainfall, has been variously interpreted. Whether plants will absorb more selenium from a particular soil in a wet than in a dry year has not been established, but the difference is probably small. It appears that the role of rainfall is important when it concerns the leaching or transport of selenium that has been made soluble through weathering of the soil or the decomposition of selenium-accumulating plants. Highly seleniferous soil areas could develop through the accumulation of soluble selenium in draws or in the subsoil where rainfall is low while the selenium might be completely leached from the soil in areas of high rainfall.

Selenium and Cattle

Much of the seleniferous area of South Dakota is grazed by cattle. The problem is therefore more acute with cattle than with other livestock. Furthermore, the prevention of selenium poisoning is much more complex where animals feed on the range than when they are confined. With hogs and poultry, for instance, proper management and the inclusion in the rations of carefully regulated amounts of drugs that prevent selenium poisoning can eliminate the problem. The costs of such practices are small. Under the presently accepted range management practices for cattle these measures of prevention become impractical.

In spite of difficulties, there are several approaches to the problem that offer promise. Reed Ranch is, of course, the proving ground for the ideas and methods developed in the laboratory. Without such a ranch, it would be difficult to establish practical control measures.

As experimental work with cattle is discussed, it will become evident that very little emphasis has been placed on the cure of symptoms. There is a reason for this. The damage done in the "alkali disease" type of chronic selenium poisoning is slow in becoming apparent. By the time the symptoms are observed a considerable amount of damage that is slow to repair has been done, and some may never be completely repaired. Prevention, therefore, is much more important than cure.

Figure 13. The Astragalus plant, a legume, tends to accumulate selenium in its seeds.

Studies with Sodium Arsenite

Sodium arsenite is toxic when fed above certain levels. It was assumed that if this compound were added to a seleniferous ration it would increase the toxicity. Experiments with laboratory animals around 1938 showed, however, that the continuous feeding of sub-toxic amounts of sodium arsenite along with seleniferous feeds actually prevented the symptoms of selenium poisoning. The results were so convincing that an experiment with cattle seemed in order.

The most practical method of getting sodium arsenite to cattle on the range, continuously and at a fairly consistent rate, was to feed it in the salt. In determining what level to use, three factors had to be considered. In the first place, salt intake by cattle will be somewhat variable. Next, sodium arsenite is itself quite toxic. Finally, arsenic tends to accumulate in tissues and if such accumulation is excessive the meat is unfit for human consumption. It was decided that in view of these factors the safe feeding of arsenic salt to range cattle could best be guaranteed by incorporating the sodium arsenite in the salt at a very low level.

The first experiment, completed in 1941, covered over 2 years. Two lots of 10 steers each were used. The two lots were alternated weekly between two seleniferous pastures at Reed Ranch during the grazing season and wintered on native and alfalfa hays which contained less than 6 p.p.m. of selenium. Both lots received salt free-choice at all times, but for one of the lots sodium arsenite was mixed into the salt. The level of sodium arsenite added varied somewhat during the experiment, but for a major part of the time it was added at a rate giving a concentration of 25 p.p.m. of arsenic in the salt.

The steers were observed for symptoms of selenium poisoning and weighed at intervals throughout the experiment. Those receiving the arsenic in their salt gained more weight, sold for a slightly higher price, and exhibited fewer symptoms than did those receiving the salt without added arsenic. It appeared from this study that even when arsenic was fed at a much lower level than would be expected to be required to prevent selenium poisoning, it had a noticeable effect.

Following this experiment, an arsenic mixture for addition to salt was supplied to ranchers who wished to try it out. The arsenic level was raised to give 35 p.p.m. in the salt. Individual reactions to its effectiveness were mixed, some ranchers indicating that they thought it was helpful while others indicated that it was not. At Reed Ranch the mixture was used continuously. Its safety for cattle was well established, but it also seemed quite obvious that it gave very little if any protection against selenium poisoning. This same observation was made at the ranch using salt containing 75 p.p.m. of arsenic.

On May 4, 1953, 28 yearling steers and heifers were placed on experiment to further study the effect of arsenic salt. The animals were divided at random into four lots, each containing two steers and five heifers. Four seleniferous pastures were fenced off and the groups were rotated between these every 2 weeks. Lots I and II were allowed salt free-choice containing sodium arsenite at a level equivalent to 35 p.p.m. of arsenic. Lots III and IV were given salt without arsenic. During winter months, native hay from the ranch and a protein supplement were provided at a maintenance level.

The cattle were weighed and observed for symptoms every 28 days. On September 23, 1954, the experiment was concluded. The results are summarized in table 5.

At the conclusion of the experiment, the cattle receiving the arsen-

Table 5. Comparison of Cattle Receiving Salt With or Without Sodium Arsenite While on Seleniferous Range (7 Animals per Lot)

Lot	Av. Initial Wt. (May 4, 1953)	Av. Final Wt. (Sept. 23, 1954)	Av. Gain in Wt.	No. Showing Severe Symptoms of Selenium Poisoning	Calves Produced by Heifers (1955)
	(lb.)	(lb.)	(lb.)		
I (arsenic)	439	915	476	1	4
II (arsenic)	447	907	460	1	3
III (no arsenic)	448	901	453	1	5
IV (no arsenic)	449	900	451	1	4

ic salt had gained slightly more than those receiving the plain salt. This advantage was not consistent throughout the experiment, however, and the difference in weight gain at the final weighing was not significant.

Only four animals showed obvious symptoms of selenium poisoning, one in each of the four lots. All of these had cracked hoofs and were stiff. Those in lots III and IV appeared somewhat more severly affected than those in lots I and II. Throughout the experiment there was no apparent difference in the general condition of the cattle. The heifers were all bred to the same bull during the summer of 1954; seven in the arsenic salt lots calved, nine in the plain salt lots.

These results indicated that while some slight advantage may have resulted from feeding sodium arsenite in the salt it was so slight as to be insignificant. Considering this, the observations previously made at the ranch when arsenic salt was routinely used, and the fact that the relative arsenic intake of the animals was far below that required for protection against selenium in laboratory animals, no advantage in using arsenic salt could be claimed. Certainly, if there is an advantage it is very slight, and the practice falls short of giving adequate control.

Figure 14. Laboratory experiments with white rats usually precede the testing done at Reed Ranch.

Organic Arsenicals

The failure of sodium arsenite to prove of much value in controlling selenium poisoning meant other measures were needed. Two of the undesirable properties of arsenic in this form which precluded its use were high toxicity and accumulation in body tissues. When it was reported that arsenic combined in certain organic chemical compounds was much less toxic, did not accumulate in body tissues, and had some growth-promoting effects similar to those of antibiotics, we became interested in these compounds. It was shown that certain of these organic arsenicals protected white rats, chickens, and swine against selenium poisoning. Work with cattle was therefore started.

Since no information regarding optimum level of organic arsenicals for cattle was available, a small pilot experiment designed to yield some information on this point was originated. The arsenical used in this trial was arsanilic acid and it was fed at the rate of 0.005 percent and 0.01 percent of the ration. A third lot received no arsanilic acid and was included as a control.

Animals available were nine steers averaging 612 pounds. These steers were randomly allotted to the three treatments and fed for 92 days. No injurious effects were noted from the feeding of arsanilic acid at these levels, although the rate of gain was slightly decreased in both of the arsanilic lots as compared with the gain in the control lot. The lot receiving 0.01 percent of arsanilic acid in its ration gained 2.38 pounds per day. The lot receiving 0.005 percent of arsanilic acid gained 2.32 pounds per day while the control lot receiving no arsanilic acid gained 2.50 pounds per day. From this rather small experiment it was concluded that these levels could be satisfactorily used in further experiments to test its ability to protect cattle against selenium poisoning.

Sixty weaning calves were started on an experiment at the station in the fall of 1955 to study the effectiveness of different levels of arsanilic acid in preventing selenium poisoning. The group of calves from the station herd included 33 heifers, 11 steers, and 16 bulls. All of the calves had been carried on seleniferous range through the preceding summer and fall and symptoms of selenium poisoning were evident in more than two-thirds of the animals.

The calves were divided by sex and randomly allotted to six pens, three pens of heifers and three of steers and bulls. The basic ration for all lots included prairie hay, salt and bonemeal free-choice plus 1 pound of 44 percent soybean oil meal per head daily. The average selenium content of the hay was relatively low, ranging from 5.4 to 7.1 p.p.m.

Two lots receiving the basic ra-

Table 6. Effect of Arsanilic Acid in Counteracting Selenium Poisoning in Beef Cattle, Winter, 1955-56

	Control (no arsanilic acid)			Low Arsenic (0.005% arsanilic acid)			High Arsenic (0.01% arsanilic acid)		
	Heifers	Steers	Bulls	Heifers	Steers	Bulls	Heifers	Steers	Bulls
Lot number	2	3	3	4	1	1	5	6	6
No. calves started	11	4	5	11	3	6	11	4	5
No. calves finished	9	4	5	11	3	6	10	2	5
Av. initial weight (lb.)	365	383	379	365	399	358	390	425	388
Av. final weight (lb.)	427	504	518	470	517	483	487	543	557
Total gain in 168 days (lb.)	107	121	139	105	118	125	97	118	169
Hay/cwt. gain (lb.)	1994	1974	1719	2028	1918	1810	2363	2100	1466
Selenium content of hay (p.p.m.)	5.7	5.5	5.5	6.6	5.4	5.4	5.9	7.1	7.1
No. showing symptoms at start	7	4	3	6	3	4	7	1	1
No. showing symptoms at finish	3	1	0	5	2	1	1	0	0

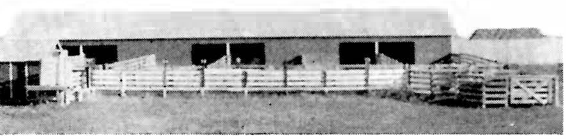
tion, one of heifers and one of steers and bulls, served as controls for the experiment. Two lots, one of heifers and one of steers and bulls, received the basic ration plus arsanilic acid comprising approximately .005 percent of the total ration, and two lots received the basic ration plus arsanilic acid comprising approximately .01 percent of the total ration. The calves were weighed and observed for symptoms of selenium poisoning every 28 days.

During the 168-day experiment five calves died—two control heifers and one heifer and two steers from the high arsenic group. None of the deaths could be attributed directly to either arsenic or selenium toxicity.

The results of the winter phase of the experiment in terms of rate of gain, efficiency of gain, and changes in visible selenium symptoms are shown in table 6. The visible symptoms of selenium toxicity decreased in all lots through the winter feeding period.

Steer and bull calves in the control group decreased in selenium symptoms at a faster rate than did the steer and bull calves in either the low or high arsenic group, while the calves in the high arsenic group were the slowest to show improvement.

Figure 15. Corrals used in winter feeding trials.



The heifers in the control group showed a somewhat slower rate of decrease in selenium symptoms than did the steers and bulls. The greatest decrease in symptoms among the heifers was noted in the high arsenic group, though only slightly greater than the decrease in symptoms among the control group. The heifer calves in the low arsenic group were the slowest to show improvement.

Results of the winter phase of this experiment were not conclusive. One lot exhibited a considerable growth response to the high level of arsanilic acid while three lots showed no such response to either level of arsenic. Arsanilic acid exhibited no material effects on the visible symptoms of selenium poisoning. Neither were any signs of arsanilic acid toxicity noted.

The winter phase of the experiment was terminated on May 18, 1956. The bull calves from this group were placed on another experiment and the heifer and steer calves were turned to pasture and were continued on the same soybean-arsanilic acid supplements they had received during the preceding winter. The heifers and steers were carried together so only three groups were maintained through the summer grazing season. The groups were rotated on three pastures to minimize the effects of pasture differences.

At the beginning of the summer period three heifers and one steer in the control group exhibited slight to moderate symptoms of selenium poisoning, five heifers and

Table 7. The Effect of Arsanilic Acid in Counteracting Selenium Poisoning in Beef Cattle, Summer 1956

	Control (no arsanilic acid)		Low Arsenic (0.005% arsanilic acid)		High Arsenic (0.01% arsanilic acid)	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Lot number	1	1	2	2	3	3
No. calves started	4	9	3	11	2	10
No. calves finished	4	9	3	11	2	10
Av. initial weight (lbs.)	504	472	517	470	543	487
Av. final weight (lbs.)	661	616	692	644	740	671
Total gain in 151 days (lbs.)	157	144	175	174	197	184
No. showing symptoms at start	1	3	2	5	0	1
No. showing symptoms at finish	2	6	1	4	0	1

two steers in the low arsenic group showed slight symptoms, and one heifer in the high arsenic group exhibited slight symptoms. The summer grazing study was continued until October 16 for a total of 151 days.

Results of the grazing experiment are presented in table 7. The effectiveness of the two levels of arsanilic acid against selenium toxicity is shown in the growth response of lots 2 and 3 compared to lot 1. In the control group the number of calves exhibiting symptoms of selenium toxicity increased during the summer, while the number of calves showing symptoms in the two arsenic groups either decreased or remained unchanged.

The effects of arsanilic acid in counteracting selenium toxicity appeared to be more clearly expressed in the summer grazing experiment. All the arsenic groups made greater gains than the control groups and the arsanilic acid did seem to exhibit some protective effect against the visible signs of selenium toxicity. Due to the relatively small size of the experiment, the results presented here do not warrant the general use of arsanilic acid as a preventive agent in selenium toxicity without further study of the problem. Additional experiments to further study the effectiveness of this compound in the prevention of selenium poisoning are now being conducted.

Effect of Rate of Grazing

It has already been pointed out that different kinds of plants vary over a wide range in their tendencies to accumulate selenium. Those plants that accumulate the most are not generally eaten by grazing animals, but they may be forced to when there is a scarcity of good grass. It is felt, therefore, that a heavily grazed seleniferous pasture will produce more poisoning than one that is properly grazed.

Around 1940, experiments were conducted at Reed Ranch to compare light, moderate, and heavy grazing rates in respect to the severity of selenium poisoning. There were no obvious differences between the three grazing rates used in this study. It cannot be concluded from this single experiment that grazing rate has no effect, but apparently any effect would be small. Continued work along this line is not considered highly important since the intensity of pasturing grassland should probably be based on what is known to be the best practice whether seleniferous or nonseleniferous range is concerned.

Linseed Oil Meal

Laboratory investigations with small animals during the early phase of selenium research indicated that protein had some protective effect against the poisoning. Linseed oil meal was later found to be more effective in this respect than many other protein supplements. Recently, it was discovered that linseed oil meal contains something beside protein that counteracts selenium poisoning in white rats. The meal was also found to be somewhat effective in this respect with swine.

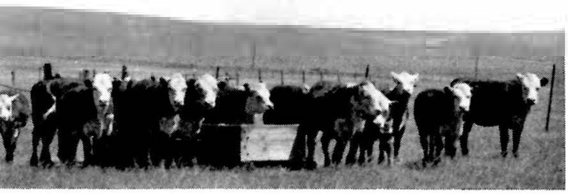
With rats and swine, the linseed oil meal had to be incorporated into the ration at a level of over 10 percent before it would show its effects against selenium. Furthermore, the meal had to be fed at all times when the animals were ingesting selenium. These limitations cast serious doubt on the possibility that linseed oil meal could have a part in the eventual control of the poisoning under range conditions. Nevertheless, some experimental work with cattle seemed desirable since predictions from the rat and swine data alone could not be expected to be highly reliable.

In the fall of 1954, 21 weanling calves—10 heifers and 11 steers—were started on an experiment designed to test the effectiveness of linseed oil meal as a protective agent against selenium poisoning in cattle. The steer and heifer calves were randomly allotted with the restriction that steers and heifers would be equally represented in each lot insofar as the odd number available would permit. Two of the lots thus had three heifers and four steers and one lot had four heifers and three steers, making a total of seven animals in each lot.

For the winter period from December 16 to April 27—132 days—lot 1 received hay alone, lot 2 hay plus 2 pounds soybean pellets per head per day, and lot 3 hay plus 2 pounds of linseed pellets per head per day.

Table 8 shows the results of this winter period in terms of gains, costs, and amount of feed required. The hay fed during this period was prairie hay produced on Reed Ranch. As can be seen from the ta-

Figure 16. Cattle on pasture wait for daily feed of soybean oil meal supplement in arsanilic acid experiment.



ble, it contained a fair amount of selenium. The hay fed to lot 1 averaged 10.4 p.p.m. of selenium, lot 2, 11.9 p.p.m., and lot 3, 10 p.p.m. These figures were obtained by daily sampling of the hay fed and chemical analysis of these samples. Even with these levels of selenium in the hay, no symptoms of poisoning were observed during the winter period.

On April 27, 1955, these three lots were turned to pasture and the protein supplements were continued at

Table 8. Linseed Oil Meal as a Protective Agent in Selenium Poisoning

	Lot 1 Hay Alone	Lot 2 Hay+2# Soybean O.M. per Day	Lot 3 Hay+2# Linseed O.M. per Day
Winter Period—132 days (Dec. 16-Apr. 27)			
Av. starting weight	321	334	341
Av. weight, April 27	358	467	487
Av. gain	36	133	146
Av. daily gain	.27	1.01	1.11
Hay consumed per animal	1288	1452	1351
Protein supplement per animal	—	264	264
Percent protein in hay	7.3	7.3	7.2
Selenium in hay—p.p.m.	10.4	11.9	10.0
Number of animals showing symptoms of poisoning	0	0	0
Value of gain one animal*	$6.12	$22.61	$24.82
Cost of protein supplement*	—	$11.35	$10.82
Value of gain less cost of supplement*	$6.12	$11.26	$14.00
Net gain from protein supplement*	—	$5.14	$7.88
Pounds of hay/cwt. gain	3578	1092	925
Pounds of protein/cwt. gain	—	198	181
Feed cost/cwt. gain	$28.62	$17.25	$14.82
Pounds of hay replaced by supplement	—	2486	2653
Summer Period—112 days (Apr. 27-Aug. 17)			
Av. starting weight	358	467	487
Av. weight August 17	542	665	652
Av. gain	184	198	165
Av. daily gain	1.64	1.77	1.47
Number of animals showing symptoms	1 slight	2 slight	5 (2 slight)
Value of gain*	$31.28	$33.66	$28.05
Cost of protein supplement*	—	$9.63	$9.18
Value of gain less cost of supplement*	$31.28	$24.03	$19.87
Net gain from protein supplement*	—	$-7.25	$-11.41
Summary—244 days			
Av. gain	220	331	311
Av. daily gain	0.90	1.36	1.27

*Prices used in cost figures—linseed $82/ton, soybeans $86/ton, value of cattle 17¢/ lb., prairie hay $16/ton.

the same rate to the two lots which had been receiving them. This summer grazing period continued until August 17 for a total of 112 days. Four small pastures were available for this work and the three lots were rotated from pasture to pasture in order that pasture differences might not affect the results.

During this summer period symptoms of selenium poisoning did become apparent in each of the three lots. In the lot receiving no supplement one animal developed slight symptoms. In lot 2 receiving soybean pellets at the rate of 2 pounds per head per day two animals developed slight symptoms. In lot 3 where linseed pellets were fed, five animals developed symptoms, two of slight nature and three rather severe. From this it was concluded that linseed oil meal at this level of feeding did not furnish protection to cattle as it had to rats and swine in previous experiments.

Bromobenzene and Related Compounds

Laboratory experiments about 1940 showed that when a chemical called bromobenzene was administered to rats on seleniferous diets, the rats excreted a high level of selenium in the urine. When this compound was administered to cattle at Reed Ranch, the selenium content of the blood was markedly reduced and excretion of the element in the urine was high. It appeared that this might serve as an aid in the cure of selenized animals.

Bromobenzene was used by others in treating what were believed to be cases of human selenium poisoning. The results were striking. However, with cattle no increased rate of recovery from symptoms of selenium poisoning has as yet been observed following administration of bromobenzene or naphthalene (another compound which was found to cause selenium excretion). Both compounds are themselves toxic, especially on prolonged administration. It is doubtful that either will prove of any practical help in the "alkali disease" problem.

Diagnosis Studies

For those acquainted with the disease, chronic selenium poisoning is usually readily diagnosed. However, there are cases where a laboratory test is desirable or necessary.

When work on a diagnostic test started, it was known that the blood of animals on seleniferous range would contain selenium. It was also known that selenium accumulated in the hair. It was not known, however, how the selenium content of blood or hair correlated with the manifestation of symptoms.

In our first study of this, blood and hair samples from cattle at Reed Ranch were analyzed for selenium at several times during the year. The selenium content of both the blood and hair increased during the grazing season and decreased during the winter feeding period. In subsequent investigations, this annual variation was again noted. This type of variation is to be expected. The selenium content of vegetation is usually highest in early summer, decreasing toward fall and remaining low during the winter.

Furthermore, the hays fed during wintering were lower in selenium content than was the growing pasture.

The variation in the selenium content of the hair was greatest in late spring, probably reflecting differences in degree of shedding at the time of clipping. The blood was no more variable at this time than that at any other time of the year.

Some blood and hair samples from cattle at other locations have been analyzed, and the results are summarized in table 9 along with Reed Ranch results. In only about 1 percent of the analyses were values of less than 1 p.p.m. of selenium obtained on the blood from Reed Ranch cattle. Most of the analyses fell between 2 to 4 p.p.m. At the Cottonwood Range Field Station, the samples of blood were taken from cattle on several pastures. No difficulty with selenium poisoning has ever been observed here, and all samples contained less than 0.5 p.p.m. of the element.

Table 9. Selenium Content of Blood and Hair of Cattle from Seleniferous and Nonseleniferous Areas

	Selenium Content of Blood				Selenium Content of Hair			
Description of Cattle	No. of Analyses	Low Value (p.p.m.)	High Value (p.p.m.)	Av. (p.p.m.)	No. of Analyses	Low Value (p.p.m.)	High Value (p.p.m.)	Av. (p.p.m.)
Reed Ranch Hereford cattle on seleniferous range; samples collected throughout the year	375	0.89	5.75	3.07	415	2.9	46.6	20.5
Reed Ranch Hereford cattle on ration containing 10 p.p.m. of selenium*; samples taken after 112 days on this ration	—	—	—	—	16	15.6	49.6	26.3
Hereford cattle on seleniferous ranch "A"	1	—	—	2.20	5	11.9	44.6	24.2
Aberdeen-Angus cattle on seleniferous ranch "A"	—	—	—	—	5	18.0	43.7	30.9
Hereford cattle from North Central Substation, Eureka	—	—	—	—	6	0.5	2.3	1.7
Hereford cattle from Range Field Station, Cottonwood	12	0.05	0.48	0.24	18	0.2	4.3	1.7

*Artificially selenized with sodium selenite.

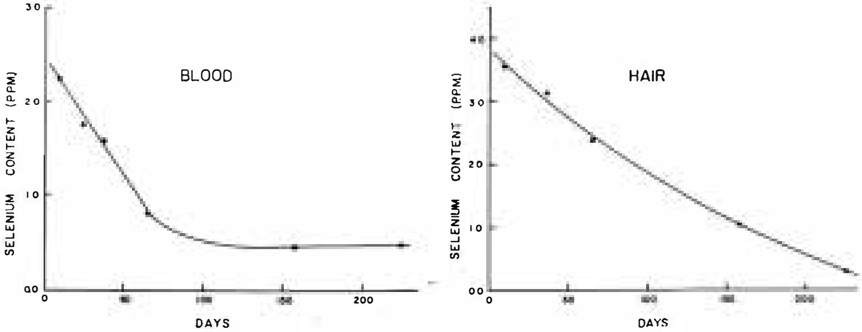
Blood analysis could no doubt be used as a diagnostic aid. From the rather limited information that we now have, it would appear that if the average value of blood selenium for a herd is over 2 p.p.m., damage from the poisoning is very likely to occur. Average values of 1 to 2 p.p.m. may indicate possible trouble and those below 1 p.p.m. probably are found where no damage from the toxicity ever occurs. More work would be necessary to establish these levels with greater accuracy.

However, the greater ease of taking, shipping, and preserving hair samples favors their use, and most of our work has therefore dealt with this phase of the study.

The hair samples analyzed in this study were collected from the side and back of the animals. Usually, about 1 square foot of area had to be clipped to obtain sufficient sample for analysis. Of the many samples taken from Reed Ranch cattle throughout the year, less than 5 percent were found to contain less than 10 p.p.m. of selenium. The animals on a ration containing 10 p.p.m. of added selenium all had more than 15 p.p.m. of the element in their hair. Some but not all of these animals developed symptoms of selenium poisoning. The comparison of Angus and Hereford cattle on the same range indicates little if any difference in the selenium content of their hair. Throughout our studies at Reed Ranch we have seen no correlation between selenium content of the hair and the occurrence of symptoms. Hair analysis

Figure 17. Clipping a hair sample for analysis.

Figure 18. Selenium content of the blood and hair of cattle at various times following their removal from a seleniferous area.



can then only indicate for us the probability of symptoms and not their actual occurrence.

The hair of cattle from areas where selenium poisoning symptoms have never been observed also contained selenium. Actually, selenium is probably present in all soils in very small amounts, so we could expect to find some in any hair sample analyzed. However, our data indicate that when less than 5 p.p.m. is found in hair from cattle no symptoms or damage from the element is to be expected. Where 5-10 p.p.m. is found as an average for a number of animals in a herd, no single sample running much above the upper limit, selenium poisoning may cause occasional trouble but not much damage should be expected. It is where values of over 10 p.p.m. are obtained that a real problem will exist. Analyses other than those listed in table 9 have been made, and have substantiated these conclusions. It should be pointed out that because of the variations between samples from various animals, single analyses should be made. The hair from at least six cattle should be clipped and analyzed for the most reliable results.

One question which arose during our studies was how soon after an animal is removed from a seleniferous range and placed on nonseleniferous feeds do the hair and blood levels fall to what might be considered normal. To determine this, six calves from Reed Ranch were brought to the Brookings station on November 2, 1954, and placed on nonseleniferous feed. These calves showed a variety of symptoms from very severe to none. On November 9 and at intervals thereafter hair and blood samples were taken for analysis. The average results obtained are given in figure 18.

The selenium content of the blood dropped rapidly and by about 60 days was within the 0-1 p.p.m. range, considered typical of cattle from areas where selenium poisoning does not occur. The decrease in the case of hair was somewhat slower, over 6 months being required for it to fall to the 0-5 p.p.m. range. The fact that animals have been on a seleniferous range can probably be detected by hair analysis for a few months after being moved to a nonseleniferous area, while with blood this could be done only for a period of a few weeks.

Research in Other Fields

While the problem of chronic selenium poisoning has received by far the most attention at Reed Ranch, experiments in other fields of research have also been carried on at times. As a general rule, such experiments have been coordinated with work at the other substations, the Reed Ranch studies comprising only a part of a project.

For many of the projects, the amount of work involving Reed Ranch has been very limited. For example, samples from the two dams have provided us information in our studies on quality of livestock waters, but information from many other sources has also been obtained. In a like fashion, grass samples from the ranch have been used in cobalt and manganese studies along with samples from many other locations.

Two experiments of major consequence have been carried on in part at Reed Ranch. These involved the wintering of beef cattle and the nutritive value of grass hay.

Wintering Beef Cows

In 1941 experiments dealing with economical wintering practices for beef cows were begun at the Cottonwood Range Field Station. In 1945 supplemental work was begun at Reed Ranch and carried on until 1950.

Four lots of bred cows were used on this experiment. During each wintering period the value of various supplements were tested. All lots were allowed winter grazing and a mineral mixture. One lot was fed a pound of 40 percent protein supplement per head per day, another a similar amount of 24 percent supplement. A third lot was wintered on a pasture where a part of the grass had been cut during the summer at an early stage, raked into windrows, and allowed to stay there for the winter. The fourth lot was pastured where an equal amount of grass was cut at an early stage, part of it being windrowed, while the rest was stacked for winter feeding following consumption of the windrowed hay.

Table 10. Changes in the Nutrient Content of Windrowed Hay and Standing Grass from July to December

	Protein (%)	Phosphorus (%)	Carotene (p.p.m.)
Windrowed Hay			
July 13	8.4	0.18	130
December 7	7.3	0.15	40
Change	−1.1	−0.03	−90
Standing Grass			
July 13	8.4	0.18	130
December 7	3.0	0.06	trace*
Change	−5.4	−0.12	−125

*5 p.p.m. or less.

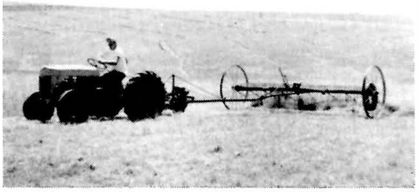


Figure 19. Early-cut hay left in the windrow for winter feed retains its nutrients better than grass that is left standing.

It was found that 1 pound of 40 percent protein supplement per animal per day did the best job of maintaining body weights in this trial. Windrowed hay and windrowed plus stacked hay gave similar results, being almost equal to the results from the 40 percent supplement. The 24 percent supplement ranked at the bottom. The average birth weights of the calves produced by the four lots of cows were highest for the 40 percent supplement and lowest for the 24.

This and other work pointed out the value of early cut hay as a wintering feed, and also showed that early cut hay left in the windrow would retain its nutrients fairly well through the winter grazing period in areas similar in climate to Reed Ranch.

Grass Hay

Parallel with the experiments on the wintering of beef cows, a chemical examination of windrowed hay versus standing grass was made at Reed Ranch. This was a part of a large experiment carried on at 11 locations in the state that showed that late cut prairie hay contained only about half as much protein as early cut hay and that its protein was not as well digested.

Hay was cut and windrowed in early July and left in the field. It was analyzed immediately upon cutting and at intervals thereafter until early December. Grass left standing on a field similar to that which was cut was also analyzed over a like period. Some of the analytical results are given in table 10.

These results demonstrate the value of early cut hay as compared to standing grass in early winter, and again show that under climatic conditions like those at Reed Ranch windrowed hay retains its nutritive value fairly well. In areas of greater rainfall the losses would be greater, and the practice of windrowing for winter pasturing should probably be confined to the area west of about the 99th meridian in this state.

Figure 20. Angus and Hereford cattle are pastured together to determine if color correlates with tolerance to selenium poisoning.

The Future

It is not possible to predict the course of future experimentation in its entirety, since laboratory studies can be expected to give further leads to control measures which must be tested under field conditions. However, the plans for the next few years have been made, and some of the work is already begun.

One of the ways in which selenium poisoning frequently causes trouble for ranchers in the affected areas is that of crippling bulls to the extent that they cannot cover their pastures. Quite often it seems that the bulls are affected more severely than are the cows.

There appear to be at least two reasons which could explain this difference. First of all it might be that there is a sex difference in susceptibility to selenium poisoning and males are more affected than are the females. On the other hand it might be that the cow herds have been carried on selenium pastures long enough that the individuals have had an opportunity to show their susceptibility and because of symptoms have been culled from the herd. If differences in tolerance to selenium are in part due to heredity, this selection would tend to build up resistance in the cow herd. Since a large proportion of the bulls brought into the herds were probably raised on feeds free of selenium, they would not have been subjected to similar selection pressure.

At present, data are being collected to determine if there is a difference between sexes in their susceptibility to selenium poisoning. It is quite possible that both of these forces are at work and other experiments are in progress to determine the extent to which heredity influences tolerance to selenium poisoning.

One of these experiments involves feeding an artificially selenized ration to the purebred bull calves to determine which are susceptible and which are resistant to selenium poisoning. Each year two susceptible and two resistant bull calves will be retained for breeding purposes. The offspring from these bulls will be subjected to a selenium ration to determine the amount of tolerance transmitted from their tested sires. If preliminary work indicates that it is advisable, a susceptible and resistant line will be established, using as a foundation the sires selected in the manner just explained.

There have been some indications both from Experiment Station herds and from private herds that the color of the animal influences its tolerance to selenium poisoning. These indications have come from experiments which were not designed to test this theory and from ranches where experimental control was not exercised.

Because of the frequency with which these reports were received and because of the quite apparent differences in swine experiments, a small herd of grade Angus cattle was acquired at Reed Ranch to test the theory under experimentally controlled conditions. Each year half of the Angus cows and half of the Hereford cows will be bred to an Angus bull, and the other half of each breed will be bred to a Hereford bull. The first calves from these matings will be dropped in 1957.

In order to determine effective experimental plans and to gain experience in working with the above problems, experiments with small animals have been initiated at the Brookings station. Plans include the use of guinea pigs, rats, and the fruit fly, *Drosophila*. These small animals have the advantage of shorter reproductive periods and more offspring per mating thus allowing the completion of experiments in a much shorter time than is possible with cattle.

Mistakes in experimental plan or in analysis can be made and corrected with little or no expense as compared with costs of mistakes in a 5- to 10-year breeding program with cattle. In addition the small animals will afford the opportunity of studying the effects of selenium in reproductive abilities. Here again the relatively high cost of beef animals makes preliminary work with small animals desirable.

Preliminary work with the flies has indicated a highly significant difference between sexes. In three experiments so far conducted, females outnumber the males when the eggs have been laid on selenium media whereas males outnumbered females when the eggs have been laid on media containing no selenium. Preliminary experiments comparing black-bodied flies with the normal gray fly have produced variable results. One stock of black flies produces more offspring on selenium media than it does on control media. However, another stock of flies which is black due to another hereditary factor does not show any more tolerance to selenium than the normal gray fly.

Initial work with the 12 laboratory stocks of flies available indicates rather large differences between the stocks in their tolerance to selenium poisoning. Further work is planned to determine to what extent these differences are affected by heredity and to determine the method of breeding which will give greatest improvement in tolerance to selenium poisoning.

It is commonly thought that grazing animals receive the largest amounts of selenium when they are grazing the first lush green growth of grass. With this in mind, an experiment has been set up to determine if cows bred just prior to or during the season of lush growth will produce more calves than cows bred later in the season after the high levels of selenium in the grass have had a chance to affect them. This project was initiated in 1956, but little critical evidence will be available for 2 or 3 years since it is possible to move the calving date up only a small amount each year.

Additional work with arsanilic acid will also be done. One experiment designed to test the effectiveness of this arsenical with a feedlot ration containing 10 p.p.m. of selenium is already under way. Further work must be done using this compound with cattle on seleniferous pasture to determine the practicability of its use and its effectiveness under these conditions. This will be started as soon as possible.

Very little is known about chronic selenium poisoning in sheep. Apparently these animals are more resistant than cattle to the poisoning, although controlled experimentation has not established this. It is hoped that in the near future some work with sheep can be undertaken. Not only do we need to know more as to their susceptibility, but we also need more information as to symptoms and the effect of selenium on wool quality. As soon as pastures are available at Reed Ranch some work with sheep will start.

Reed Ranch will continue to serve in studies on soils and plants. Some of this work will concern selenium, but other trace minerals may also be investigated where the nature of the work does not interfere with the major program on selenium poisoning. Some additional plant sample analysis is necessary to give a more accurate map of the selenium content of vegetation at certain locations on the ranch, but the amount of this type of work remaining to be done is limited. Other work on selenium will deal with chemical forms of selenium in the soil and factors affecting uptake of this element by plants.

Whereas there is much known concerning the effect of selenium on farm animals, very little information is available relative to its effect on the human being. Reed Ranch can be expected to yield only a small fraction of what knowledge is needed in this field, but there are some background data that can be obtained there. For instance, the selenium content of various types of vegetables grown on soils of known selenium content can be established. Eggs, meat, and milk from animals on seleniferous feeds can be analyzed and their possible contribution to the selenium in the diet can be determined. These data alone will have limited value, but as others in the field of public health make progress in establishing levels of selenium required to produce toxic symptoms in the human being they will become very important. Whenever possible, therefore, such data will be collected.

Published Literature Pertaining to Work at Reed Ranch

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Seasonal changes in the manganese content of grasses. Proc. S. Dak. Acad. Sci. 27:97, 1948.

A new aid in diagnosing selenium poisoning. S. Dak. Farm and Home Research 6:12, 1954.

Cobalt in our grasses. S. Dak. Farm and Home Research 6:84, 1955.

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IF YOU HAVE A SPECIAL PROBLEM

If you have questions that concern selenium poisoning, send your inquiry to either Station Biochemistry or the Animal Husbandry Department, South Dakota State College, College Station, Brookings, South Dakota. Hair, grain, or forage samples can be analyzed for selenium, when necessary, by Station Biochemistry.

The Animal Husbandry Department will answer questions concerning feed or roughage quality. Where analyses are needed, these are done by Station Biochemistry for a small charge. Before sending samples, be sure of what you want. Your County Agent can help you decide this.

If you do not send samples through your county agent, be sure that you label the package correctly and fully and that you write a letter to accompany it. The analyst must know exactly what analysis you wish made or details as to why you want the sample examined. With this information he can keep the cost to you at a minimum and give you an answer in the shortest time.