MINERAL AND MANAGEMENT STUDIES WITH RANGE BEEF CATTLE

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PART I

THE EFFECT OF PHOSPHORUS IN DRINKING WATER, TRACE MINERALS, INTERNAL PARASITE TREATMENT, AND ARTIFICIAL SUMMER SHADE FOR BEEF CATTLE.

INTRODUCTION

For the past several years reproduction of experimental beef cattle in the Wilburton area of southeast Oklahoma has been sub-normal. The cows appeared to be unthrifty, and showed a definite lack of condition throughout the winter months. Weaning weights of calves and subsequent growth of heifers was also poor. Farmers in the Wilburton area have reported similarly sub-normal performance of beef cattle.

In 1947 an experiment was begun at Wilburton to determine the phosphorus requirements of range beef cattle. The data obtained seemed to indicate that (1) the presence or absence of some nutritional factor (s) and/or (2) the lack of some management practice(s) was detrimentally affecting the reproduction and lactation of the cows. The indication became more apparent when the data were compared to data of a similar trial at Stillwater, Oklahoma. It was noted that the cows at Stillwater made much larger gains during the summer than did the Wilburton cows. The cows at the Stillwater station also produced a higher percentage of calves, and at weaning time the calves averaged 91 pounds more than the Wilburton calves. The percentage calf crop among the Wilburton cows ranged as low as 20 per cent in one lot. Considerable difficulty was experienced with death losses at time of calving or soon after. During the summer months, the inorganic phosphorus content of the plasma was much higher among the Stillwater cows than in the Wilburton cows.

The primary differences in the two experiments were the initial weights of the cows and the forages fed to each group. The cows at the Stillwater station were slightly heavier at the beginning of the experiment than the Wilburton cows. During the winter period both groups were fed 1.25 pounds of corn gluten meal per head daily plus prairie hay free-choice. The Wilburton group was fed hay grown in the Wilburton area, and hay grown in the Stillwater area was fed to the Stillwater group. Each group grazed in its respective area.

There were several suggested causes as to the reproductive difficulties reported in experimental cattle in southeastern Oklahoma. Some of the suggestions were lack of summer shade, internal parasitism, deficiency of trace minerals, and insufficient phosphorus intake, due to low bone meal consumption, and a deficiency of phosphorus in the forage. The experiment reported in part one of this thesis was initiated to determine the effects of parasite treatment, artificial summer shade, trace minerals, and an increased level of phosphorus intake, on the performance of range beef cows.

REVIEW OF LITERATURE

Phosphorus

According to Maynard (1947), a phosphorus deficiency is known to exist in Michigan, Texas, Minnesota, Wisconsin, Kansas, Montana, Florida, Utah, and California. Nelson et al. (1951) reported a borderline deficiency in some soils of central Oklahoma, and a definite phosphorus deficiency in some ares of southeastern Oklahoma.

In the absence of sufficient phosphorus for cattle, their body stores are depleted, and aphosphorosis occurs. Eckles et al. (1932) experimentally produced symptoms of aphosphorosis in dairy cattle. A ration supplying 0.9 gram of phosphorus per 100 pounds body weight was fed to growing heifers, and pica, retardation of growth, listlessness, and stiffness were observed. Plasma phosphorus data were obtained for the entire period. The plasma phosphorus level dropped as low as 1.68, and the entire 360 day average was 2.5 mg. per 100 ml. of blood. Supplementation with phosphorus resulted in a return to high plasma levels in all cases, usually within 15 to 20 days. These workers also observed a decrease in milk production and a reduction in the percentage of bone ash in the skeleton, when a phosphorus deficient ration was fed. Normal calcium values were observed throughout the entire period.

Cattlemen in certain areas of Texas observed that some of their cattle appeared stiff, weak, and emaciated. These cattle were called "creeps", and were associated with a phosphorus deficiency. Some of the phosphorus supplements used failed to completely alleviate the symptoms of the deficiency. Tash and Jones (1947) initiated an experiment in

1941 to determine the most effective means of phosphorus supplementation for range cattle. In this experiment, cattle in Group 1 served as a non-treated control. The cows of Group 2 received bone meal free-choice. Group 3 cows were given disodium phosphate in the drinking water, to supply approximately 6.5 grams of phosphorus per head daily. The cows of Group 4 were fed defluorinated superphosphate in the water from 1941 to 1943, disodium phosphate in cottonseed meal from 1943 to 1945, and from 1945 to 1946 were fed disodium phosphate in self-feeders. The cows of Group 5 were allowed to graze on pastures fertilized with 200 pounds triple superphosphate per acre. The control group was characterized by numerous cases of "creeps" among the lactating cows, low inorganic phosphorus content of the blood, subnormal body development, reduced fertility, lighter calves, and several deaths. Of the phosphorus treatments used, the controlled phosphorus intake in the water was most effective. No cases of aphosphorosis were noted in this group. Satisfactory results were obtained from the other phosphorus supplemented groups, however, the intake was variable and some mild cases of a deficiency were noted. Although phosphorus fertilization of the soil resulted in an increased carrying capacity of the pastures and sufficient phosphorus intake by the cattle, a severe two-year drouth occurred which eventually resulted in a shortage of green forage, and aphosphorosis symptoms occurred.

In an earlier experiment on the King Ranch in south Texas, Black and associates (1943) used four groups of crossbred cattle. The cows of Group 1 served as the untreated control group. Those of Group 2 were fed 6.5 grams of phosphorus per day as bone meal for dry cows and heifers, and 14.3 grams per day for lactating cows. The cows of Group

3 were fed the same levels of phosphorus as Group 2 in the form of disodium phosphate, and those in Group 4 were fed bone meal and trace minerals. Feeding the mineral supplement resulted in heavier calves at weaning, a larger calf crop, and better condition of the cows.

Knox and coworkers (1941) conducted an experiment to determine the phosphorus requirement of range cattle on native grass pastures of New Mexico. They found that cattle fed a phosphorus supplement produced calves that were 80 pounds heavier at weaning than calves from non-supplemented cows. The phosphorus content of the forage consumed by the cows ranged from 0.048 per cent to 0.136 per cent. The cattle consumed from two to three grams of supplemental phosphorus per head daily for the entire three-year period.

Nelson et al. (1951) fed dicalcium phosphate as a phosphorus supplement to a ration deficient in phosphorus. The daily intake of this element during the winter was approximately 7.6 grams of phosphorus for cattle of Lot 1, 12.5 grams for Lot 2 cattle, and 19.2 grams of phosphorus for those of Lot 3. The low level of phosphorus was inadequate for normal growth of weanling calves and normal performance of the cows in southeastern Oklahoma, whereas there were no differences observed in the cows or their calves on the medium or high level of phosphorus intake. An intake of 12.5 grams of phosphorus per head daily was considered an adequate amount for range cows by these workers.

Huffman and coworkers (1933) reported that 10 to 12 grams of phosphorus per day for dairy cattle from 18 months of age to time of calving provided adequate phosphorus for maintenance, growth, and development of the fetus. Phosphorus requirement for milk production was found to be 0.5 to 0.7 gram of feed phosphorus per pound of milk produced. The maintenance allowance was placed at 10.0 grams daily per 1000 pounds of body weight. Nance (1952) recommended a daily dietary intake of 1.5 grams per 100 pounds of body weight for range cows.

It has been observed by many workers that a deficiency of phosphorus may be the cause of various kinds of breeding trouble. Jordan and associates (1906) found that the feeding of a phosphorus deficient ration for a long period of time caused a disappearance of the estrus cycle.

Eckles and coworkers (1926) observed dairy cows in certain sections of Minnesota that were suffering from a phosphorus deficiency. The cows were producing calves at the rate of one every two years. When fed bone meal at the level of two per cent of the ration, practically all the cows returned to normal breeding habits and optimum milk production. Theiler (1928) found that only 51 per cent of a group of cows fed no phosphorus supplement calved normally, while 80 per cent of the cows fed bone meal calved normally. Reduced mortality of the cows and calves, and superior growth and development of the calves was noted among the phosphorus supplemented cattle. Lantow (1932) fed supplemental phosphorus to one lot of range cows, while another lot served as a non-supplemented control. He found that cows fed additional phosphorus matured earlier, produced larger calf crops, had lower death rates, and produced heavier calves at weaning.

Reid (1949) stated that many cases of reproductive failure in cattle on phosphorus deficient ranges may not be entirely due to a lack of this element since the low content of phosphorus in forage is usually accompanied by a low level of protein. Palmer and associates (1944) concluded that a combined deficiency of phosphorus and protein in the bovine, analogous to similar deficiencies in animals reared largely on prairie hay in the phosphorus deficient regions, delayed sexual maturity and repressed normal evidences of estrum so that periods of estrum appeared to be missed.

It has been observed by several investigators that a phosphorus deficiency interferes with feed utilization. Eckles and Gullickson (1927) concluded from their experiments that cows on a low phosphorus diet needed at least 20 per cent more digestible nutrients to maintain their weight than was indicated by Morrison's standard.

Riddell and Hughes (1934) conducted experiments to determine feed utilization with phosphorus deficient cows. They found that dairy cows in a condition of aphosphorosis digested their feed as well as control cows. They did note, however, that the phosphorus deficient cows showed a higher energy metabolism than did the controls.

Kleiber and coworkers (1936) found that heifers fed a ration containing 0.13 per cent phosphorus ceased to grow after six months. Heifers on a 0.4 per cent phosphorus ration continued to grow. It was found that phosphorus deficiency lowered the total efficiency of energy utilization mainly by lowering the appetite and secondly by lowering the partial efficiency, whereas it did not seem to influence the fasting catabolism.

The inorganic phosphorus content of the blood of cattle has been studied for several years as a measure of the adequacy of the diet in this mineral, and also as a common method of diagnosing aphosphorosis. According to the literature, a wide range of plasma phosphorus levels may be considered normal. Maynard (1947) stated that the inorganic phosphorus levels of the blood usually range between 4 and 9 mg. per 100 ml. of plasma depending upon the age and species. Watkins and Knox (1948) reported that breeding cows had good production records and maintained satisfactory body weights with an average phosphorus level varying from 2.11 mg. during the winter to 5.37 mg. per 100 ml. of plasma in the summer. The normal plasma phosphorus level according to Dukes (1947) for the bovine is 2.3 to 9.6 mg. per cent.

As reported by Loosli et al. (1950), the normal inorganic phosphorus value for cows is 4 to 6 mg. per cent, and for calves under one year, 6 to 8 mg. per cent of the plasma.

Moxon (1947) determined inorganic plasma phosphorus levels of 88 range cattle over a period of five years. The levels showed a range of 1.19 to 9.57 mg. per 100 ml. plasma, with a mean value of 4.77 mg. per cent. Palmer (1930) observed that the average inorganic phosphorus level was 5.87 mg. for mature cows, and 7.56 mg. per cent for calves up to 185 days old. He stated, however, that there was a great day to day, and even hourly variation in the plasma phosphorus levels of mature cows. Drinking, eating, and exercising appeared to cause some of the variation.

Different methods of phosphorus supplementation and different phosphorus supplements have been used by different workers with varying results. In this regard, Hodgson and coworkers (1948) found that both bone meal and defluorinated superphosphate supplied satisfactory phosphorus intakes when force-fed, but when fed free-choice bone meal was far more palatable and larger amounts were consumed by the cattle than of the less palatable superphosphate. Both supplements were eaten more readily when mixed with salt than when fed alone.

Bekker (1932) and Du Toit (1939) found that phosphorus supplementation in the drinking water was very effective, provided the water supply was controlled. Tash and Jones (1947) found that disodium phosphate dissolved in water was a more satisfactory means of phosphorus supplementation than feeding bone meal free-choice, disodium phosphate mixed with cottonseed meal, disodium phosphate free-choice, or dissolved defluorinated superphosphate in water.

Trace Minerals

It has been shown that the animal body requires iron, copper, iodine, zinc, and cobalt. If these elements, required in only very small amounts, are not supplied in adequate amounts the animal eventually develops characteristic symptoms of the mineral deficiency. Since these elements are required only in such small amounts, they are known as trace minerals.

Copper and Iron

Hart et al. (1928) observed that a small amount of copper is necessary, along with iron for hemoglobin formation. It was not found to be a constituent of hemoglobin, but did occur as hemocuprin in the blood cells. Cunningham (1931) stated that the chief activity is in the liver, which is considered to function in converting inorganic iron to organic iron, possibly to the form of iron porphyrin. Lahey et al. (1951) noted that on a diet low in copper, iron absorption from the intestinal tract of swine was reduced, and when iron was administered intravenously, only 20 per cent was utilized for hemoglobin formation. This study suggested that copper functioned in the absorption as well as utilization of iron. Underwood (1940) found that in the rat, copper was essential in hemoglobin formation, but was not concerned with iron assimilation. Maynard and Loosli (1943) suggested that copper might function as a component of oxidation--reduction systems.

Allcroft and Parker (1949) reported a disorder affecting dairy cattle that was associated with copper deficienty. The condition was characterized by severe and persistent diarrhea, unthriftiness, low milk production and marked degree of stunting in young stock. Forbes (1918) found that although copper and iron were stored in the fetus in sufficient amounts for normal hemoglobin formation, long periods of nursing depleted these stores, resulting in anemia and listlessness in dairy calves. Hart (1928) noted that the levels of both copper and iron were very low in milk, and supplementation of these elements to the cows failed to raise the levels of copper and iron of the milk. According to Huffman (1947), the primary symptom noted as a result of iron deficiency in dairy calves was anemia. The anemic condition affecting milk-fed calves usually was alleviated when the calves were allowed to eat grain and roughages.

Carpenter (1947, 1948, 1949) compared 11 ppm. of copper to 45 ppm. of copper as a supplement to young pigs and found that the pigs receiving the higher level of copper gained an average of 16 pounds more than the pigs receiving 11 ppm. in a period of 70 days. Later work showed that sows given 35 ppm. of copper farrowed 10.3 pigs per litter as compared to 7.8 pigs per litter from sows receiving 7 ppm. He later found that he could increase liver stores of copper in pigs by feeding copper supplements to their mothers.

According to Maynard (1947) 7.5 ppm. of copper in the forage is sufficient to maintain the normal 100 microgram percent copper level in the blood of cattle.

Iodine

Maynard (1947) reported that the thyroxine secreted by the thyroid gland of the animal body is 65 per cent iodine. The clinical symptoms of iodine deficiency in farm animals have been described by Welch (1917, 1928, 1940) as the birth of weak or dead foals; dead, weak, "big necked", sometimes hairless calves; dead, weak and often partially wooled lambs; and the birth of edematous, flabby and hairless pigs. Goiter is sometimes apparent in the newborn in all classes of livestock.

Morrison (1939) reported that deficiency of iodine in older animals caused goiter, an enlargement of the thyroid gland. He also stated that "there is no need of supplying additional iodine to pregnant animals in areas where there has been no trouble from goiter in newborn animals". Hamilton and Kick (1930) failed to obtain any response by adding supplemental iodine to a ration with a borderline deficiency of iodine for growing chicks. Carroll et al. (1930) obtained similar results by feeding potassium iodide to pigs on a ration low, but not deficient in iodine. Maynard (1947), however, reported that supplementary iodine, when fed to sows in a borderline area of iodine deficiency, resulted in larger numbers of live pigs at birth, and larger per cent of pigs farrowed.

In an experiment with sheep and swine, Andrews and coworkers (1948) observed the effects of a ration deficient in iodine. These workers noted that when ewes were fed a ration with no additional iodine, 60 per cent of their lambs showed a hyperplasia of the thyroid, and only three of 147 lambs had normal iodine levels in the thyroid gland. When stabilized iodized salt was fed to another flock of ewes on the same iodine deficient ration, only one lamb was observed to have an enlarged thyroid, and all glands contained normal amounts of iodine. A ration deficient in iodime was fed to swine, with no additional iodine added. In practically all cases, the pigs from the iodine deficient sows showed some evidence of goiter, and iodine levels were consistently lower than normal. When iodized salt was added to the ration of the sows, all pigs were normal with respect to thyroid size and iodine levels in the thyroid.

Cobalt

Marston (1938) definitely established cobalt as an essential element for cattle and sheep. McCance and Widdowson (1944) have shown that cobalt is evidently essential for the metabolism, growth, and reproduction of the microflora present in the rumen. Smith (1951) reported that cobalt functioned in the production of vitamin B_{12} in the rumen of sheep, probably by microbial synthesis. Rickes et al. (1948) isolated vitamin B_{12}, a factor that contains cobalt, from the liver. Hale (1949) reported a definite increase in B_{12} synthesis in cobalt supplemented sheep over sheep on a cobalt deficient ration.

Becker and Smith (1951) found that a cobalt deficiency did not markedly affect the cellulose splitting microorganisms of the rumen. However, Gall and coworkers (1949a, 1949b) found that the oral administration of 1 mg. of cobalt per day for sheep resulted in a count of 54.6 million microorganisms per gram of rumen material. This was compared to 30.2 million for cobalt deficient sheep, and 30.4 million for sheep injected with one mg. of cobalt per day. A simpler kind of flora and lower bacterial count were also noted in cobalt deficient sheep.

Chamberlain and coworkers (1948) found that during the last four weeks of a 14-week feeding trial, cobalt supplemented lambs outgained those of the cobalt deficient lot by 9.5 pounds. The cobalt fed lambs required only 90 per cent as much feed as the control group.

Orten and coworkers (1932) fed rats 0.5 mg. of cobalt in addition to copper as a supplement to a milk and iron diet. This resulted in polycythaemia, an excess of red blood cells. Underwood (1940) reported a polycythaemia in swine when cobalt was fed in large amounts. Dinusson et al. (1950) found that cobalt increased daily gains when fed to swine in dry lot. Robison (1950) also reported a growth response from added cobalt when pigs were fed an all plant ration .

In a series of in vitro experiments, Burroughs et al. (1950a, 1950b, 1951) showed that alfalfa ash, a synthetic sheep saliva plus trace minerals, a water extract of alfalfa, a water extract of manure, and rumen liquid increased the digestibility of low quality roughage, but had little effect on high quality roughage. Swift et al. (1951) fed alfalfa ash to sheep with a ration in which ground corn cobs made up the entire roughage fraction, and found that the average digestibility of every ration constituent was increased, but only crude fiber and total digestible nutrient values were significantly increased. Chappel et al. (1932) obtained similar results by adding alfalfa ash to a ground corn cob basal ration. A synthetic alfalfa ash improved digestion of organic matter and crude fiber, but the results were less favorable than those obtained from natural ash. A mineral mix including sodium chloride, potassium chloride, manganese, zinc, iron and copper failed to improve the digestiblility of any ration constituent.

Pope and coworkers (1953) summarized three years of work with yearling and two-year old steers, and reported no beneficial effect was noted by using a trace mineral mix containing cobalt, manganese, zinc, copper, and iron. Nelson and associates (1951) added iron, cobalt, iodine, manganese, and copper to a ration for weanling heifers and reported no difference in gain or general appearance after two years work.

Bentley and Moxon (1952) compared alfalfa ash, a trace mineral mix (cobalt, zinc, manganese, copper, and iron), and reduced iron as a supplement to a ration of urea, cerelose, iodized salt, calcium carbonate, calcium phosphate, vitamin A and D oil, corn and cob meal, and poor quality, late cut timothy hay. Alfalfa ash and mineral mix improved the average daily gain by 43 per cent, whereas iron fed alone had no effect on growth performance. None of the supplements appeared to improve digestibility of the ration, but the trace mineral mix and alfalfa ash effected a saving of 12 per cent of the corn and cob meal, and increased the consumption of corn and cob meal by 25 per cent.

Speer and coworkers (1952) added a mineral mix containing iron, copper and manganese, cobalt, and zinc to a growing fattening ration for pigs. They found that average daily gains of the mineral supplemented pigs were significantly higher than those of the control pigs. Willman and Noland (1949) found that supplementary cobalt, copper, iron, and manganese improved both growth and feed efficiency in growing swine.

Parasite Control

There are three species of roundworms, Haemonchus contortus, Ostertagia ostertagi, and Trichostrongylus axei, that are commonly referred to as parasites of the abomasum or fourth stomach of cattle. Of these, the first is the best known as is commonly referred to as the stomach worm or twisted wireworm. Ransom (1906) experimentally traced and first described the life cycle of the twisted wireworm in 1906. Veglia (1915) reported the occurrence of H. contortus in South Africa, and Dikmans (1912a) reported the presence of the stomach worm in the abomasum of cattle and sheep examined in a local slaughterhouse. Ackert and Muldoon (1920) reported cases of Strongylosis, caused by O. ostertagi among yearling steers.

Porter (1942) has described the roundworm, H. contortus, as being about one-half inch to one and one-fourth inches long. Female worms deposit their eggs in the stomach of the host, which passes them out in the feces. The eggs hatch in a few hours, under favorable conditions, into the larval stage. The larvae undergo two molts, and reach the infective stage in four or five days. When there is rain or dew, the larvae climb up a blade of grass and are eaten and swallowed by the host. They mature in the abomasum in three or four weeks. Veglia (1915) stated that constantly moist, cloudy weather, dew at night, and an abundance of soil covering were the conditions most favorable to the life cycle. Swanson (1942, 1945) found that the stomach worm larvae could survive on native pasture for a six and one-half to twelve month non-grazing period. Ransom (1906) reported that freezing did not affect the larvae.

Upon reaching the stomach, the larvae undergo two more molts. According to Porter and Cauthen (1946) the larvae enter the gastric pits and fundic glands of the abomasum where they mature. They then localize as adults, in the pyloric region. Eggs are found in the feces 19 to 31 days after the larvae are swallowed.

Porter (1942) reported that the common symptoms of stomach worm infestation are: loss of flesh; general weakness; anemia, noted by a paleness of skin and epithelium of mouth and eyes; bottle jaw, an edema of the lower jaw; and diarrhea. Clunies Ross (1933) experimentally infected lambs with stomach worms and failed to note diarrhea, however, anemia did occur in all cases.

An observation into the condition of anemia and gastric hemorrhage caused by stomach worms was made by Andrews (1942). Nineteen lambs, two to eight months old, were infested with 2,000 to 181,000 _H. contortus_ larvae in single and multiple doses. One lamb was bled at daily intervals to produce an experimental anemia. Blood appeared in the feces of the infected animals six to ten days after infection. The amount of blood in the feces was determined for the entire period. Two of the lambs died of parasitism. They had passed in their feces, 1,492 cc. and 2,380 cc. of blood, or 1.57 and 2.5 times respectively, their original blood volume. The lamb that had been bled had lost 3,500 cc. of blood, or 2.5 times its original volume. It was concluded that the anemia of the infested lambs was due to gastric hemorrhage alone. Martin and Clunies Ross (1934) calculated that 2,000 female stomach worms could withdraw about 30 cc. of blood each day from a host animal. That amount did not include blood removed by the male worms. Wells (1931) actually observed blood passing through the bodies of hookworms imbedded in the intestinal mucosa of a dog. He calculated that 1,000 hookworms could withdraw 360 cc. of blood per day.

It was noted that lambs harboring considerable numbers of parasites exhibited little obvious evidence of ill health when feed conditions were satisfactory. (Clunies Ross, 1936). Vegors and coworkers (1953) studied the effect of three types of winter pastures along with corn supplementation on internal parasite infestation, with yearling beef calves. The calves were allowed to graze on a temporary pasture of rye grass, oats and crimson clover, a fescue-white clover mixture, or a crimson clover pasture. Half the calves on each pasture were supplemented with corn. It was noted that the corn supplemented calves had only one-fourth as many parasites as did non-supplemented calves. The calves on fescue pasture without supplement had an average of 101,000 worms, and gained only 1.13 pounds per day, as compared with 2.31 and 2.94 pounds per day gain for the calves on the crimson clover and temporary pastures. The three most prevalent parasites found in the calves on autopsy, were _Cooperia punctata_, _Ostertagia ostertagi_ and _Trichostrongylus axei_. Taylor (1934) demonstrated that lambs receiving a full feed of hay and concentrates contained fewer worms at autopsy than did lambs fed a ration of hay alone.

Foster and Cort (1931, 1932, 1935) found that dogs fed a good diet were resistant to reinfection with hookworms, while the same dogs when fed a poor diet were very susceptible to reinfection. Weir et al. (1948) reported that lambs on a ration of grass and legume hay, corn, and soybean meal continued to gain, even though some were heavily infested with stomach worms. Porter et al. (1941) experimentally infected one each of two pairs of calves with stomach worms. After eliminating the worms, the calves were put on an infested pasture. It was found that previously infected calves were resistant to reinfection, while the others were readily infected.

Most species of stomach and intestinal worms of cattle are also present in other ruminants. Clunies Ross (1931) reported that lambs may be parasitized by H. contortus of either ovine or bovine origin. Trichostrongylus axei is the least host specific of the internal parasites. These worms have been observed by Stoll (1936) and Taylor (1937) to occur in horses, cattle, sheep, and other ruminants. Cooperids, a group of intestinal worms common to sheep, have been used by Edgar (1936) to produce fatal infections in young goats. They have also been observed in cattle. (Dikmans, 1939 and Ransom, 1920).

Although H. contortus is the most common and probably the most economically important internal parasite, there are several others which are common to this area. Verminous gastritis, caused by O. ostertagi, has been noted among cattle in Texas by Barger (1927). Occurring among yearling cattle, it caused emaciation, anemia, rough haircoat, diarrhea, bottlejaw, and even death. Porter (1942) described O. ostertagi as about one-fourth inch long, and occuring in the fourth stomach of ruminants. Its life history differs from the stomach worm in that the larvae penetrate and mature in the mucous membrane of the abomasum, in small cystic nodules produced by the host. *Ostertagia circumcincta* and *O. trifurcata* have been observed in calves, but were of little significance compared to *O. ostertagi*.

Trichostrongylus axei, another of the roundworms, was described by Porter (1942) as being very slender and only about one-fifth of an inch long. Baker (1939) reported that "*T. axei* caused a patchy gastritis in which the stomach lining was thrown into folds". The symptoms were similar to those of *H. contortus*, with the loss of condition and severe diarrhea occurring most commonly.

Dikmans (1939) and Ransom (1920) reported a severe inflamation of the intestinal wall of calves caused by Cooperids, specifically *Cooperia punctata* and *C. pectinata*. These Cooperids or intestinal worms, caused a destructive inflammation of the layer beneath the intestinal mucosa, resulting in the accumulation of white or yellow cheesy material. Seriously affected calves appeared anemic, emaciated, and showed a persistent diarrhea. Andrews (1939) experimentally infected lambs with *C. curticei*, *C. oncophora*, *C. puntata*, and *C. pectinata* and observed that there was a decreased ability of the animals to convert feed to gain, but no symptoms of infection were noted.

Ortlepp (1939) found that the hookworm, *Bunostomum trigonocephalum*, was capable of entering the body through the skin, as well as through the intestinal tract. Infection with hookworms caused an abstraction of blood from the host, in addition to the secretion of a hemolytic substance which destroyed red blood cells, and prevented coagulation of the blood. This prolonged hemorrhage, after the worm had moved, along with the blood removed by the parasite, caused anemia, edema, and other symptoms identical to those caused by stomach worms.

One of the first chemicals used in controlling internal parasites was carbon tetrachloride. This was employed by Dikmans (1921b) on cattle that were infected with wireworms, O. ostertagi, and Cooperids. Later, the use of copper sulfate and nicotine sulfate became widespread. Whitehurst (1942), however, in a preliminary trial with sheep, found that copper sulfate and nicotine sulfate did not alleviate parasitism with stomach and intestinal worms.

Harwood and coworkers (1939) first introduced phenothiazine as an anthelmintic agent. The administration of phenothiazine by capsule, removed 87 per cent of the internal parasites. Habermann and Harwood (1940) in further studies with phenothiazine, obtained similar results, but reported the ineffectiveness of a one per cent solution of copper sulfate in removing stomach worms of rams. Shorb et al. (1941) compared phenothiazine to copper sulfate and nicotine sulfate in studies with 115 naturally parasitized sheep. The phenothiazine removed 99 per cent of the wireworms, and 95 per cent of the other roundworms. It was far more effective than any other drench.

Peterson (1943) suggested a one to 14 phenothiazine-salt mixture for ewes and lambs. He found that this mixture reduced, but did not eliminate parasitization of sheep on previously infected pastures. He calculated that each sheep consumed approximately 0.54 gram of phenothiazine per day. Thorp (1943) and Willman (1943) recommended a phenothiazine drench for sheep in the spring and fall, with a salt-phenothiazine mixture during the summer. Thorp and Henning (1945) compared the efficiency of a salt-phenothiazine mixture to a drench for ewes and lambs for the removal of eight different nematodes. They found that a drench of 12½ grams of phenothiazine, and a one to nine phenothiazine-salt mixture were most effective in removing the parasites. It was also noted that the lambs did not consume enough of the salt mixture for it to be effective. No residual effect of phenothiazine on ewes was observed.

Winchester and Herrick (1946) compared copper sulfate, nicotine sulfate, and phenothiazine, with and without cobalt, for drenching ewes and lambs. They found that in flocks where cobalt was not used, 30 per cent of the lambs died. When cobalt was used, only 3 per cent of the lambs were lost. Phenothiazine was twice as effective as any other drench used. Weir and coworkers (1948) added trace minerals, soybean meal, and bone meal separately and together to a basal ration of mixed grass and legume hay and corn for lambs. The lambs of group one were infected with 4,000 and 28 days later 15,000 more wireworm larvae. Group two lambs received 4,000 and 40 days later 45,000 more wireworm larvae. It was noted that there were more worms in the sheep that received trace minerals. "Apparently at a low level of infection, trace minerals helped to ward off infection, however, at a high level of infection, the reverse was true."

Swanson (1941a) found that phenothiazine was highly effective in removing nodular worms from swine. Swanson (1941b) reported that only 2 per cent of 537 cattle infected with stomach and intestinal worms failed to show great improvement when given an 80 gram dose of phenothiazine. He suggested a 30 to 40 gram dose of phenothiazine for calves under 150 pounds, 50 gms. for 200 pound calves, 60 gms. for 300 pound calves, and 70 gms. for yearlings.

The variation of the egg content of sheep feces has been reported by Spedding (1952). He noted that the variation was such that when only a few sheep were used, the count was more accurate when the eggs were determined on a per day basis. When large numbers of sheep were used, the eggs per gram basis was quite accurate. Thorp et al. (1944) could detect no difference in the egg counts of heavily parasitized sheep, as compared to sheep with small numbers of worms.

Shade

Heat is being produced constantly in the body as a result of physiological oxidations. There must, therefore, be some provision for insuring a constant heat loss. Heat is regularly lost from the body by radiation, convection, conduction, vaporization of water from the skin and respiratory passage, and as feces and urine loss (Dukes, 1947). The point of hyperthermal rise is defined by Dukes as the environmental temperature at which physical mechanisms of heat dissipation fail to maintain a constant body temperature. The point of hyperthermal rise is 70 to 80 degrees for Jerseys and Holsteins, and 90 to 95 degrees for Brahmans (Kibler and Brody, 1950).

Ragsdale et al. (1948) stated that head dissipation is very difficult in non-sweating animals at air temperatures of 70 to 80 degrees Farenheit. According to Rhoad (1936), temperatures in excess of 85 degrees F. have a marked detrimental effect upon production, and feed utilization in cattle.

Regan (1938) noted that composition changes began to occur in the milk of dairy cattle when they were subjected to a temperature of 80 degrees F. . Kibler et al. (1949) reported that dairy cattle decrease heat production from 30 to 40 per cent when the ambient temperature rises from 80 to 100 degrees F. Part of this decrease was due to lowered feed consumption and milk production. However, Dempsey and Astwood (1943) indicated that temperature increases in the environment of a rat caused a decreased thyroxine production and thus a lowered heat production. Heitman et al. (1951), using pregnant sows in a psychrometric chamber, noted a 50 per cent decrease in feed consumption at temperatures of 89.5 to 99 degrees F.

Since temperatures in southern United States range high above 85 degrees in the summer, there is definitely a problem of decreased production in beef and dairy cattle.

Of all the methods employed to keep cattle comfortable in the summer, probably the use of shade is the most widespread and economical. Miller and coworkers (1951) supplied artificial shade in the pastures of dairy cows. They found that at temperatures of 80 to 85 degrees F. the cattle spent 63 per cent of their time grazing. At temperatures of 86 to 91 degrees the cows spent only half as much time grazing. The cows spent the rest of the time in the shade. When temperatures reached 97 degrees, the cattle spent only one-third of the daylight hours grazing, again spending the majority of their time in the artificial shade. In another experiment with dairy cows Seath and Miller (1946a) reported at an average daily temperature of 86 degrees, cows grazed only 1.8 hours during the day and 5.7 hours at night. When the average temperature dropped to 72 degrees, 4.5 hours per day and 4 hours each night were spent grazing. The animals entered the shades at about 9:20 each morning, and remained until milking time at 3:00 P.M. Body temperatures did not begin to rise until after the cattle had been in the shade about 1 hour. Although there was a body temperature increase to 102.4 degrees F. in the shade (normal 101.1 ± .5, Gaalaas, 1945) the cows appeared to be more comfortable in the shade.

Kelly and Ittner (1948) compared wood slat, hay covered, aluminum covered, and galvanized iron covered shades for cattle at the El Centro station in California. They noted that at an air temperature of 100 degrees, the underside of the galvanized iron shade was 126 degrees, the aluminum shade was 110 degrees, the wood slat shade was 109, and the hay covered shade was 105 degrees F. Although there were no significant differences among any of the shades, cows under the aluminum and hay covered shades had a lower body temperature and respiratory rate, consumed slightly more feed, and had a slightly higher rate of gain.

In later work at the same station, Ittner and Kelly (1951) used a galvanized iron shade as a control and compared it with: (1) a shed, three sides enclosed, and equipped with an evaporator cooler (Desert Cooler); (2) an aluminum covered shade, with a burlap bag subroof, cooled with dripping water which also dripped on the cattle; and (3) a hay covered shade with a tilted aluminum sub-roof which was constantly sprinkled with water. In this trial, Hereford and Braford steers were fed a ration of good quality alfalfa hay. One pound barley per head daily was added during the last month. Only weights of the Hereford steers were checked. The average daily gain for the control steers was 0.69 pound, steers in the evaporater cooled shade gained

1.05 pounds per day, those in the water cooled burlap shade gained 0.80 pound per day, and those in the water cooled aluminum shade gained 0.89 pound daily. There was definitely a sanitation problem with the burlap shade, in which water dripped down on the steers. One of the steers in this group was continuously scouring throughout the entire experiment. If the data from this steer were not included, the average daily gain for this group would be 1.02 pounds. Respiration rates of the steers ranged from 80 per minute in the burlap shade to 116 per minute in the control group.

In a subsequent study in this experiment, two hay covered shades, one seven feet high and one 12 feet high, and two louvered board slat shades, six and nine feet high, were used. Steers in the hay covered shades appeared to be more comfortable, with the 12 foot shade apparently more effective. Calculations with a flat plate radiometer showed that the heat load by radiation was reduced eight to 10 B. T. U.'s per hour more per square foot of skin area under the 12 foot shade, than under the seven foot shade. These workers assumed that the higher shade gave the cattle greater exposure to the relatively cooler portion of the sky. Reinerschmid (1943) found that solid roofed shades reduced radiation by 65 per cent, whereas radiation by slat covered shades was reduced 55 per cent.

Seath and Miller (1948a) tied six dairy cows in the sun from noon till 2:00 P.M. for 12 days. Each day after exposure the cows were driven into a barn, half were sprinkled with water (85 degrees), and half were not. On alternate days, the cows were allowed to stand in fromt of a fan. The cows that were sprinkled with water were cooled significantly faster than the non-sprinkled cows. Similar results were obtained with fanning, and the fastest cooling occurred when the cows were both sprinkled and fanned. There was a similar decrease in respiration rate, but it was not proportional to body temperature. In another experiment, Seath and Miller (1948b) located shades with and without sprinklers in the pastures of dairy cows. They found that shade alone was sufficient to reduce body temperatures from 104.8 to 101.9 degrees F. Sprinkling with water further reduced body temperatures to 100.76 degrees. Respiratory rates followed a similar trend, 113 per minute in the sun, 85 per minute in the shade, and 56 per minute under the sprinkler.

Heitman and Hughes (1949), in a similar experiment with swine, subjected hogs to a temperature of 115 degrees F. Water (100 degrees) was then poured on the floor. Within 90 minutes, the body temperature of the hogs was reduced two degrees, and the respiration rates from 150 to 30 per minute. When air motion was added, cooling was more rapid. Under the same temperature conditions on a dry floor, no apparent cooling was detected.

Since in the above mentioned experiments the cooling effect of water was attributed to evaporation, and since a high relative humidity reduces evaporation, there should be some consideration to the effect of relative humidity on body temperatures. Heitman and Hughes (1949) stated that a relative humidity increase of 30 to 94 per cent at 96 degrees F. increased both body temperatures and respiratory rates of swine. Tidwell and Fletcher (1951), however, found that with pigs weighing 116 to 183 pounds, the highest respiratory rates occurred on days of highest temperature and lowest relative humidity. Lowest respiratory rates occurred on days of lowest temperature and highest humidity. They also noted that a significant positive correlation existed between body temperature and respiratory rate. Seath and Miller (1946 b) reported that a one degree increase in air temperature was responsible for 13 to 15 times as much increase in body temperature as was an increase of one per cent humidity. A one degree increase in air temperature had 41 to 43 times as much influence on respiratory rate as did a one per cent increase in relative humidity. Pulse rates were affected more by body temperature than by air temperature or relative humidity. The values, determined by multiple correlation, were all approximate for the year in which they were taken, and there would be some year to year variation.

Although cattle do not have sweat glands, there is some water loss, other than by the respiratory tract or by the feces and urine. As stated by Rhoad (1936), at a temperature of 84 degrees F. and a relative humidity of 60 per cent, a cow loses one pound of water per hour from the surface of her body by transpiration. According to Kibler and Brody (1950 b), at a temperature of 80 degrees, and an 800 to 900 pound Jersey cow loses 30 pounds of water daily from the surface of her skin. The water loss by insensible perspiration by cattle on a maintenance ration was two to three times greater than that passed in the urine. This loss, according to Kendall (1931), may vary up to 12 or more pounds per day, with decreases accompanying a drop in air temperature. Each pound of moisture lost from the body carried with it 1,086 B. T. U.'s of heat. Kelly et al. (1948) found that 1,050 B. T. U.'s of head per pound of water was lost, as water vapor left the body.

Forbes and coworkers (1932) noted that 40 per cent of the heat left the cow's body as latent heat of water vapor. Brody (1945) and Kleiber (1945), reported that cattle on full feed dissipate 20 to 30 per cent of the gross energy of the feed as heat.

Ittner and coworkers (1951) studied the effects of cooled drinking water (65 degrees) for cattle. They found that cooling the drinking water lessened the heat load on the cattle about 2800 B. T. U.'s per day. This is compared to a head load reduction of 1344 B. T. U.'s per hour when using artificial shade at a temperature of 100 degrees F. They also noted that there was only a 0.49 gallon increase in cooled water consumption when the mean air temperature increased 8 degrees F. Cattle that had access to water at a temperature near the temperature of air (101 degrees) consumed 2.23 gallons per day more with the same increase in ambient temperature. There was a saving of 375 pounds of feed per 100 pounds gain by the cattle drinking cooled water.

Thompson et al. (1949) reported that at temperatures under 85 degrees, Jerseys consumed much more water per 100 pounds body weight than did Brahmans. At temperatures over 85 degrees, there was very little difference in water consumption of the two breeds. Heitman and Hughes (1949) observed that as the temperature increased, water consumption in hogs decreased. Regan and Mead (1939) obtained similar results with dairy cows in a psychrometric chamber in which temperature and humidity were controlled.

In all experimental work reported in which Brahman or Brahman crosses were used, it was observed that they spent less time under the shades, made higher daily gains, and were generally more comfortable than pure bred or grade cattle of the European breeds. Rhoad (1938) reported that time spent by cattle in the shade is associated with heat tolerance. Rhoad (1942) at the Jeanerette experiment station tested more than 150 cows, heifers, and steers of various breeds and crosses for climatic adaptability. He derived this heat tolerance formula; 100-10 (BT - 101), in which BT is body temperature, 10 is the factor to convert degrees deviation in body temperature to a unit basis, and 100 is perfect efficiency in maintaining body temperature at 101 degrees F. The heat tolerance for a purebred Brahman is 93, the highest of any breed of cattle in America. Grade Herefords have a heat tolerance coefficient of 73. The Brahman and Africander crosses, and dairy breeds range somewhere between 73 and 93. Gaalaas (1947) used a slightly different formula for calculating heat tolerance; $HT=100-14(BT - 101)$. He found very little yearly variation in heat tolerance of a herd, and no difference in heat tolerance with respect to gestation and lactation, sire or dam.

EXPERIMENTAL

The following experiment was started in the fall of 1951 at the Range Cattle Minerals Station at Wilburton. Sixty two-year-old grade Hereford heifers were divided into six equal lots. Five heifers of each lot were obtained from a commercial herd in southern Oklahoma, and were bred to Angus bulls. The other five were from the grade herd at Stillwater, and were bred to Hereford bulls. All heifers were allowed to graze on native grass pasture the year around and had access to loose salt (free-choice). For simplicity of presentation, the experimental phase is divided into two periods, a wintering period and a summer period.

During the winter Lots 1, 2, 4, and 5 received 2.5 pounds of cottonseed cake plus enough steamed bonemeal to supply 8.45 grams of phosphorus per day. Lots 3 and 6 received in addition to the above, the following amounts of trace minerals per 100 pounds of body weight: Iron, 10 mg.; copper, 1.0 mg.; cobalt, 0.2 mg.; and iodine, 0.2 mg.

During the summer, Lots 1 and 4 received supplemental phosphorus in a mixture of two parts salt and one part bone meal. This mixture was offered free-choice. Lots 2 and 5 were force-fed phosphorus by dissolving monosodium phosphate in their drinking water. The cows were allowed to drink from tanks, and approximately 3.63 grams of monosodium phosphate were added to each gallon of water, supplying approximately 0.9 gram of supplemental phosphorus per gallon of water. Lots 3 and 6 also received phosphorus in the drinking water at the same level as Lots 2 and 5, plus the same trace minerals that were given in the winter. However, during the summer the trace minerals were mixed with salt in such amounts that each ounce of salt mixture would contain 85 mg. of iron, 8.5 mg. of copper, 1.7 mg. of cobalt, and 1.7 mg. of iodine. Therefore, the actual nutritional treatments of Lots 1 and 4, 2 and 5, and 3 and 6 were the same. However, Lots 1, 2, and 3 were provided with artificial summer shade, while Lots 4, 5, and 6 had no artificial shade.

To test the value of internal parasite control in the same experiment, one-half of the cows in each lot and their calves were drenched with phenothiazine. The cows were treated six times at one to two month intervals, from January 29 until September 5. Each cow received 62.5 grams of phenothiazine per dose. Calves were treated three times at approximately two month intervals beginning May 29. The initial calf dosage was 12.5 grams, the second was 25 grams, and the third was 37.5 grams of phenothiazine per head. Fecal samples were taken from the cows on January 29, and from the calves at weaning time, October 24, for worm egg counts.

Bulls were placed with the cows on May 1 and were removed September 1. The bulls were rotated between lots at 14 day intervals during the breeding season to minimize differences due to heredity and breeding efficiency. Each of the lots of cows was rotated among pastures at each weigh date throughout the year. Four artificial shades were arranged among the six 100-acre pastures so that Lots 1, 2, and 3 had access to artificial shade throughout the summer period.

The average calving date was in March, and the calves were weaned October 24. Blood samples were taken from the jugular vein of one-half of the cows in each lot, at one or two month intervals. The blood was analyzed for plasma phosphorus, hemoglobin, and red blood cells. Weight data were obtained at the time blood samples were taken. Grass samples were taken in November, February, April, June, and September for analyses of ash, protein, ether extract, nitrogen-free extract, calcium, and phosphorus. Each sample was a composite of the three predominant grasses, big bluestem, little bluestem and Indian. The chemical analyses of the feeds and grasses are presented in Table 1.

Table 1. Chemical Composition of Feeds and Grasses, 1951-52

Feedstuff	Percent Composition of Dry Matter						
	Ash	Protein	Ether Extract	Fiber	N.F.E.	Calcium	Phosphorus
Cottonseed cake	6.84	44.08	7.28	11.66	30.14	0.40	1.36
Bone meal	87.75	4.72	----	----	7.53	32.65	15.53
Grasses:[1]							
November (1951)	8.57	3.37	1.45	35.59	51.02	0.37	0.04
February (1952)	7.83	3.29	1.69	35.09	52.10	0.37	0.03
April (1952)	10.32	17.91	2.44	22.33	47.00	0.43	0.29
June (1952)	7.65	8.62	1.83	31.91	49.99	0.32	0.10
September (1952)	6.87	4.52	2.17	33.59	52.85	0.42	0.06

[1] An average in each case of the three predominant grasses: big bluestem, little bluestem, and Indian.

RESULTS AND DISCUSSION

It will be noted in Table 1 that the protein and phosphorus levels of the grasses were highest in April, decreased rapidly as the plants matured, and reached their lowest levels during the winter season.

Phosphorus in Drinking Water

Table 2 exhibits the production and weight data of the cows and calves. It will be noted that the effect of phosphorus in the water can be determined by comparing Lots 1 and 4 to Lots 2 and 5. There was very little difference in the initial weights of the cows among the lots. It is also apparent that there were very small differences at the end of the wintering period.

During the summer period, Lots 2 and 5 were fed phosphorus in the drinking water, while Lots 1 and 4 were fed bone meal, and the supplemental phosphorus intake of the cattle by lots is shown in Table 3. It can be seen that the daily supplemental phosphorus intake was approximately 14 grams per animal in Lots 2 and 5 while those fed phosphorus in the salt-bone meal mixture received only 1.35 grams per day. Although the weight differences were small, the cows of Lots 2 and 5 gained slightly more during the summer period than did the cows in Lots 1 and 4.

There was a small weight difference in favor of the calves of Lots 2 and 5. There was no difference in the percent of calf crop or the number of calves weaned. This indicates that the cows received an adequate amount of phosphorus in the summer forage, making any additional intake of phosphorus in drinking water of no apparent value. These data would

Table 2. Performance of Cows and Calves at Wilburton, 1951-52

	Artificial shade in summer			No shade in summer		
	Lot 1 Bone meal in salt	Lot 2 Phosphorus in water	Lot 3 Phosphorus in water trace minerals	Lot 4 Bone meal in salt	Lot 5 Phosphorus in water	Lot 6 Phosphorus in water, tr. minerals
Number of cows per lot	10	9[1]	10	10	10	10
Average weight of cows (lbs.)						
Initial 8-3-51	805	808	814	809	806	807
Before calving 3-3-52	798	782	786	789	762	800
End of winter 4-11-52	721	716	794	759	755	734
Final 11-7-52	894	913	942	898	895	886
Weight gain or loss (lbs.)						
Winter loss to calving	7	26	28	20	44	7
Total winter loss	84	92	20	50	51	73
Summer gain	173	197	148	139	140	152
Yearly gain	89	105	128	89	89	79
Number of calves weaned	9	8	9	8	9	8
Average birth weight of calves (lbs.)	66	74	68	68	64	67
Average weaning weight of calves (lbs.)[2]	403	406	433	422	428	447

[1] One cow in Lot 2 died due to paralysis at calving.

[2] Corrected for age, sex, and for breed of sire.

tend to support the work of Nelson et al. (1951), who found that a total daily intake of 12.5 grams of phosphorus was as satisfactory as 19.2 grams for range beef cows. It is also possible that the storage of phosphorus during the winter period was sufficient to maintain adequate phosphorus levels throughout the summer.

Table 3. Supplemental Phosphorus Intake at Wilburton, 1951-52.

	Grams per cow daily					
Lot number	1	2	3	4	5	6
Winter	8.45	8.45	8.45	8.45	8.45	8.45
Summer	1.35	14.20	13.90	1.35	14.30	14.60

Table 4. Blood Constituents of Cows at Wilburton, November, 1951 to September, 1952.

	November	December	January	March	April	May	July	September
	Phosphorus (mg. per 100 ml. plasma)							
Lot 1	4.23	6.17	5.14	5.04	4.10	4.10	4.17	4.12
Lot 2	4.66	7.74	7.61	5.53	4.29	4.11	6.32	6.15
Lot 3	4.50	7.29	6.51	5.67	4.32	5.02	5.54	5.49
Lot 4	4.18	7.52	6.73	5.63	4.50	5.13	3.91	4.30
Lot 5	3.86	6.38	6.14	4.97	4.10	4.43	5.68	6.13
Lot 6	4.35	7.22	6.69	5.94	5.74	5.27	5.76	6.40
	Hemoglobin (gm. per 100 ml.)							
Lot 1	12.18	12.76	12.08	12.24	12.34	12.52	12.62	12.00
Lot 2	12.30	12.70	11.80	12.20	11.90	11.70	12.26	12.98
Lot 3	12.28	13.10	12.40	12.30	11.80	12.40	12.98	12.68
Lot 4	12.30	12.40	12.06	11.66	11.50	12.70	12.30	12.30
Lot 5	12.90	12.90	12.60	12.20	12.70	12.30	13.00	12.50
Lot 6	12.40	12.60	12.20	12.00	11.90	12.40	12.30	11.40
	Red blood cells (millions per cu. mm.)							
Lot 1	7.67	7.62	7.06	7.41	7.54	7.39	7.51	6.84
Lot 2	7.56	7.75	7.06	7.38	7.14	7.09	7.11	6.92
Lot 3	7.55	8.22	7.27	7.45	7.46	7.28	7.48	7.18
Lot 4	7.29	7.78	7.13	6.97	6.70	7.25	6.98	6.82
Lot 5	7.88	8.13	7.34	7.07	8.66	6.97	7.36	6.99
Lot 6	7.60	7.75	7.17	7.00	7.71	7.02	7.05	6.54

A summary of the blood constituents is presented in Table 4. The lowest phosphorus values occurred in November, 1951, when the cows were placed on the experiment. The average plasma phosphorus values were raised from approximately 4 to approximately 7 mg. per 100 ml. of plasma during the month of December. This increase in the inorganic phosphorus levels was apparently due to the bone meal and cottonseed cake supplementation.

The higher intake of phosphorus by Lots 2 and 5 apparently had no effect upon the plasma phosphorus value until the phosphorus content of the forages had decreased. It can be noted in Table 1 that the phosphorus value of the forages was rather low from June throughout the remainder of the summer. It can also be noted in Table 4 that the plasma phosphorus levels of Lots 1 and 4 were lower during the latter part of the summer than those of Lots 2 and 5.

The hemoglobin and red blood cell values were remarkably uniform among all lots throughout the entire year.

Trace Minerals

The actual daily intake of trace minerals for Lots 3 and 6 is shown in Table 5. The average yearly weight gain of the cows receiving trace minerals throughout the year in addition to phosphorus in drinking water during the summer period (Lots 3 and 6), was slightly larger than that of the cows receiving phosphorus in drinking water without trace minerals (Lots 2 and 5).

There were no differences in per cent calf crop or birth weights of calves when Lots 3 and 6 were compared to Lots 2 and 5. Although the weight differences between the cows were slight, the calves from the cows fed trace minerals averaged 23 pounds heavier at weaning than calves of Lots

2 and 5. The differences were not statistically significant, however, they did approach significance, and further research is necessary before conclusive statements can be made. Nelson et al. (1952) failed to obtain beneficial results by feeding a similar trace mineral mixture to growing heifers.

The differences in blood constituents between cows fed trace minerals and those which did not receive trace minerals were very small.

Table 5. Intake of Supplemental Trace Minerals at Wilburton, 1951-52

	Mg. per cow daily			
Trace mineral:	Iron	Copper	Iodine	Cobalt
Winter (Hand-fed)				
Lots 3 and 6	85.00	8.50	1.70	1.70
Summer (In salt)				
Lot 3	79.20	7.92	1.58	1.58
Lot 6	63.20	6.32	1.28	1.28

Parasite Control

A summary of the production and weight data for the parasite control experiment is presented in Table 6. There were no appreciable differences between the weight gains of cows drenched with phenothiazine and cows which were not treated. The treated cows had an average yearly gain only 5 pounds more per head than the untreated cows. The average birth weights of the two groups of calves were identical and there was little difference in the average weaning weights of the treated and untreated calves.

Fecal samples were taken from the cows in January and the calves in October, and a very light and uniform infestation with internal parasites was indicated by the egg count. Several eggs present in the fecal samples of both treated and untreated calves were described by the examining veterinarian as being infertile. Provided the infestation was not heavy enough to visibly affect the health and general appearance, or to decrease gains in the cows and calves, drenching with phenothiazine would not show any beneficial effect on the weight gains of cows or on the growth and thriftiness of calves. However, Clunies Ross (1936) reported that visible symptoms of internal parasite infestation were not observed in lambs when feed conditions were satisfactory, even though the lambs harbored considerable numbers of internal parasites.

Table 6. The Effect of Parasite Control on Cows and Calves, 1951-52.

	Parasite treatment (5 cows from each lot)	No parasite treatment (5 cows from each lot)
Number of cows	30	29
Average weight per cow (lbs.)		
Initial 8-31-51	826	789
End of winter 4-11-52	764	730
Final 11-7-52	925	883
Winter loss (lbs.)	62	59
Summer gain (lbs.)	161	153
Yearly gain (lbs.)	99	94
Number of calves weaned	26	25
Average birth weight of calves (lbs.)	68	68
Average weaning weights of calves (lbs.)[1]	421	427

[1] Corrected for age, sex, and for breed of sire.

The differences in blood constituents between cows treated with phenothiazine and untreated cows were very small.

Artificial Summer Shade

The effect of summer shade is summarized in Table 7. The cows with access to artificial summer shade (Lots 1, 2, and 3) had an average yearly gain of 116 pounds per head, as compared to 86 pounds per head for Lots 4, 5, and 6 which had no summer shade. The cows of Lots 1, 2, and 3 gained an average of 20 pounds more per head during the summer than did the cows without shade. The differences between the two groups were most noticeable during July, August, and September. The cows with shade averaged about 25 pounds per head heavier during this period than the cows without shade.

Table 7. The Effect of Summer Shade on Cows and Calves, 1951-52

	Summer shade Lots 1, 2, and 3	No summer shade Lots 4, 5 and 6
Number of cows	29	30
Average weight per cow(lbs.)		
Initial 8-31-51	809	807
End of winter 4-11-52	761	749
Final 11-7-52	925	893
Winter loss (lbs.)	48	58
Summer gain (lbs.)	164	144
Yearly gain (lbs.)	116	86
Number of calves weaned	26	25
Average birth weight of calves (lbs.)	69	66
Average weaning weight of Calves (lbs.)[1]	412	430[2]

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[1] Corrected for age, sex, and for breed of sire.

[2] The difference in weaning weight (18 lbs.) in favor of calves without shade was statistically significant ($P = < 5$ per cent)

The calves without shade had an average weaning weight of 430 pounds, as compared to 412 pounds for the calves with shade. This difference of 18 pounds in favor of the calves without shade was statistically significant ($P = < 5$ per cent). It was observed that during the hot summer period, cattle with artificial shade spent part of their time in the shade whereas cattle without shade remained in the pastures. It is possible that the calves without shade spent more time grazing than did calves with access to shade. Seath (1948b) in a trial with dairy cows, reported that at an average daily temperature of 90 degrees F., two yearling heifers had lower respiration rates and body temperatures, spent more time grazing, and less time under the shade than did the older dairy cows.

SUMMARY

An experiment was initiated at the Range Cattle Minerals Station at Wilburton, Oklahoma, in the fall of 1951. Sixty two-year-old grade Hereford heifers were divided into six equal lots. All cows were fed bone meal and 2.5 pounds of cottonseed cake per head daily during the winter. Lots 3 and 6, in addition to bone meal and cottonseed cake, received the following trace minerals, with the approximate intake of each per 100 pounds of body weight daily: iron, 10 mg.; copper, 1.0 mg.; cobalt, 0.2 mg.; and iodine, 0.2 mg.

During the summer, Lots 1 and 4 were fed supplemental phosphorus as bone meal, mixed with salt. Lots 2, 5, 3, and 6 were force-fed phosphorus by dissolving monosodium phosphate in drinking water. Lots 3 and 6 were fed the same trace mineral mixture as in the winter, mixed with salt. One-half the cows and their calves in each lot were drenched with phenothiazine. Lots 1, 2, and 3 were provided with artificial summer shade, while Lots 4, 5, and 6 had no artificial shade.

1. The cows fed monosodium phosphate in the drinking water during the summer consumed slightly over 14 grams of phosphorus per head daily as compared to 1.35 grams for the cows fed bone meal free-choice in a salt-bone meal mixture. The additional phosphorus intake was of no apparent benefit, either to the cows or calves.

2. The feeding of a trace mineral mixture consisting of iron, copper, cobalt, and iodine had no important effect on the cows.

3. Calves from the cows fed trace minerals had an average weaning weight 23 pounds heavier than the calves from cows fed a comparable ration without trace minerals. Apparently, the feeding of a trace mineral mixture had some beneficial effect on the calves.

4. One-half the cows in each lot and their calves were drenched with phenothiazine. There were no differences in the performance of cattle treated for internal parasites and those not treated. A determination of the number of eggs present in the feces indicated only a mild infestation in some of the cattle.

5. The cows which had access to artificial shade during the grazing period gained more weight during the summer months and consequently had larger yearly gains than did cows without shade. However, calves without shade had an average weaning weight 18 pounds heavier than calves with shade. The use of artificial shade in the summer appeared to depress the weaning weights of calves.

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PART II

THE EFFECT OF HIGH LEVELS OF MANGANESE INTAKE ON THE PERFORMANCE OF RANGE BEEF COWS

INTRODUCTION

Simultaneous experiments were conducted at Wilburton in southeast Oklahoma, and at Stillwater in north central Oklahoma, to determine the phosphorus requirements of range beef cattle. It was observed that some soils in north central Oklahoma were on a borderline phosphorus deficiency, while most of the soils in the southeastern Oklahoma area are known to be deficient in phosphorus.

In the two experiments, a low, medium, and high level of phosphorus was fed to beef cows. The cattle at Wilburton, although showing an improvement in reproductive performance when fed supplemental phosphorus at both levels, did not perform nearly as satisfactorily as did the cattle located at the Stillwater station. The yearly gains of the cows, percentage calf crops, and weaning weights of the calves were notably smaller at the Wilburton station. Also, death losses of calves at calving time were extremely high.

Subsequent studies were conducted at Wilburton to determine the importance of feeding a trace mineral mixture to weanling and yearling Hereford heifers. It was concluded from the data obtained, that it was not beneficial to feed the trace mineral mixture.

It was observed by analyses, that the forage grown in the Wilburton area contained a much higher manganese content than that of forage grown near Stillwater. These analyses showed that hay grown near Wilburton contained from 150 to 270 ppm. of manganese, while some weeds contained as much as 700 to 900 ppm. Hay produced near Stillwater contained 25 to

75 ppm. of manganese. Some workers reported that a high level of manganese in the ration of cattle was detrimental, causing various reproductive difficulties and decreased gains.

The experiment reported in part two of this thesis was conducted to determine the effect of high levels of manganese on reproduction, blood constituents, and weight gains of range beef cows.

REVIEW OF LITERATURE

It has been shown that manganese is an essential constituent of the animal diet by Waddell (1930), and by Orent and McCollum (1932). These workers reported that rats fed a diet deficient in manganese grew normally, but their haircoats became rough after approximately 8 months. The males had testicular degeneration and the females failed to suckle their young properly. Daniels (1934) observed congenital debility in rats, apparently the result of insufficient manganese in the diet of the mother. Amdur (1945) observed inferior bone development in rats on low manganese diets as compared to rats fed adequate amounts of manganese. Smith and coworkers (1944) reported severe bone malformation in rabbits on manganese deficient rations.

Lardy and Boyer (1942) at Wisconsin, reported that bull calves fed rations containing 28 ppm. of manganese showed poor semen quality. Bentley et al. (1951), in later work, reported that breeding trouble occurred in bulls on rations containing 20 ppm. of manganese, while 10 to 20 ppm. was considered sufficient for cows. When the manganese levels fell below 10 ppm. for prolonged periods (4 to 6 months), various reproductive failures were observed.

Grummer et al. (1950) added 40, 80, and 160 ppm. of manganese to a basal ration of corn, soybean oil meal, corn gluten meal, ground alfalfa, salt and limestone for 4 lots of pigs. The pigs receiving 40 ppm. of manganese gained faster and were more efficient in gain in each of 4 trials. When sows were fed 40, 80, and 160 ppm. of manganese, fertility was improved but lactating ability was not. Johnson (1944) reported satisfactory gains with pigs fed a ration containing 7 to 10 ppm. of manganese. Miller (1940) observed lameness in pigs which weighed about 150 pounds. This lameness was attributed to a manganese deficiency in the ration. He found that manganese sulfate supplements prevented the condition, but were ineffective in curing the lameness after it had developed. Keith (1942) also found that the addition of manganese to a low-manganese ration helped prevent, but did not cure lameness in pigs.

Work by Johnson (1940) at the Arkansas station showed that ewes on a ration containing less than 10 ppm. of manganese actually lost weight over a period of 5 months, while ewes receiving 100 ppm. of manganese gained an average of 42 pounds.

Several workers have demonstrated that manganese is an essential element for poultry. It has been shown that "slipped tendon," an abnormal condition in chicks, can be prevented by supplying sufficient manganese. Norris (1938) found that hens on a low manganese diet produced chicks with tibiae which were 12.5 to 13.1 percent shorter at 1 day of age than the tibiae of chicks from hens fed a high manganese diet. The long bones of the legs were still shorter after three weeks. Caskey (1939) fed chicks a ration deficient in manganese and found that they developed bone structures significantly shorter than chicks on an adequate manganese intake. It was concluded that the shortening of the bones was due to an upset in the calcium and phosphorus metabolism produced by a manganese deficiency.

Apparently a small amount of manganese is an essential dietary constituent for livestock. However, large amounts may be harmful to animals. Grummer (1950) conducted an experiment to determine the effect of a high level of manganese on the growth of pigs. One lot of pigs was fed the basal ration, the second lot was fed the basal plus 500 ppm. of manganese.

The pigs on the basal gained 1.21 pounds per day as compared to 0.97 pound for the pigs receiving an additional 500 ppm. of manganese. The additional manganese retarded growth and appetite, especially during the latter part of the trial.

Dairy cattle rations were supplemented with various levels of manganese, calcium, and trace minerals by Reid et al. (1947). The addition of manganese sulfate and additional calcium carbonate resulted in a negative calcium balance in every case. "The marked depression of calcium metabolism appeared to be effected by manganese sulfate supplementation." There was no appreciable effect on the phosphorus metabolism.

Blakemore and coworkers (1938) believed that grasses particularly high in manganese would possibly lower the blood magnesium, thus contributing to laçtation tetany of cows and sheep. Monier-Williams (1949) reported that grass containing 540 to 132 ppm. of manganese was thought to be concerned with lactation tetany.

Nelson and coworkers (1952) conducted an experiment to determine the effects of high levels of manganese supplementation on beef cows. Cows in Lot 1 served as controls. The cows in Lot 2 were fed enough manganese sulfate to supply a total of 250 ppm. of manganese. Those of Lot 3 were fed enough additional manganese sulfate to supply a total of 500 ppm. of manganese. The cows of Lot 4 were fed a total of 500 ppm. of manganese plus small amounts of iron and copper. The feeding of manganese sulfate in relatively large amounts to beef cows resulted in decreased yearly gains. There were no differences in the weaning weights of the four lots of calves.

von Oettingen (1935) observed gastritis, vomiting, and paralysis in dogs fed high levels of manganese.

Nelson and associates (1929) observed a growth stimulation when 100 ppm. of manganese sulfate was added to a basal of casein, dextrin, and salt for rats. Growth was retarded when 600 ppm. of manganese sulfate was added. In a study conducted by Chornock (1942) with rats, an increased calcium and phosphorus excretion resulting in a negative balance of both elements was effected by increasing the manganese intake. It was also observed that when the rats were fed a rachitogenic diet plus manganese, growth was retarded in proportion to the manganese content of the ration. As little as 100 ppm. of manganese effected a slight growth depression.

Blumberg and coworkers (1938) produced a condition which they called "Manganese rickets" in rats, by adding 2.9 percent manganese carbonate to a stock ration of optimal calcium and phosphorus content, and by adding 2.9 percent of manganese carbonate to a high calcium and low phosphorus diet. It was reported that manganese carbonate was rachitogenic, but manganese oxide, being more insoluble was not. "The manganous ion forms an insoluble phosphate in the gastro-intestinal tract."

Nance (1952) conducted an experiment to determine the effect of high levels of manganese on reproduction, lactation, and growth of rabbits. He found that the addition of 1000 ppm. of manganese to a basal ration of prairie hay, corn gluten meal, ground wheat. ground oats, alfalfa meal, Delsterol, and salt resulted in an apparent impairment of the reproduction and lactation of the does. When 2000 ppm. of manganese was added to the basal ration, growth was retarded in each trial. The retardation of growth was partially counteracted by bonemeal supplementation.

Skinner and Peterson (1931) fed various levels of manganese to rats. Female rats on a manganese intake of 5 mg. per rat daily were unable to properly nourish their young after several litters. In young growing rats, it was noted that decreases in storage of manganese caused by the addition of (1) copper, (2) iron, and (3) a combination of the two, to the manganese-milk ration were 27 percent, 20 percent, and 26 percent respectively. It was also noted that there was a marked retention of manganese by the rats fed manganese plus milk, as compared to those receiving only milk. Skinner (1931) later found that female rats fed 10 mg. of additional manganese per day plus the stock ration were as successful in rearing their young as the females on the stock ration alone. Even when 2,000 ppm. of manganese sulfate was added to the ration of weanling rats for 12 weeks, no retardation of growth was noted.

The toxicity of manganese chloride for rats was determined by Becker and McCollum (1938). Manganese levels from 499 to 9980 ppm. were added to a stock ration containing 0.72 percent phosphorus and 0.63 percent calcium. The only retardation of growth was noted at the 9980 ppm. level. Reproduction, however, was normal on the high manganese ration. These workers assumed that "the high level of phosphorus in the ration prevented toxicity symptoms from occurring by reducing the amount of absorbable manganese."

Perla and Sandberg (1939) found that a disturbance in the lactation of female rats, caused by the addition of 2 mg. of manganese to the stock ration, could be alleviated by feeding thiamine. It was noted in the same experiment that 2 mg. of manganese chloride per rat daily counteracted the toxic effects produced by parenteral administration of high levels of thiamine. Perla (1939) reported supporting evidence on the toxicity of high levels of thiamine and the effectiveness of manganese in alleviating the symptoms of the toxicity. "It was reasoned that perhaps manganese was essential as an oxidative catalyst in the utilization of vitamin B_1 by the animal." Nance (1952) reported that brewer's yeast completely counteracted the growth retardation caused by high levels of manganese in the ration of rabbits. Perla and coworkers (1939) also found that a larger amount of manganese was stored when thiamine was added to an unusually high manganese ration.

Ray and Deysach (1942) reported that in guinea pigs, excess manganese was stored in the thyroid out of all proportion to that stored by other organs. As the manganese content of the thyroid increased, oxygen consumption decreased. Reineke and Turner (1945) demonstrated that the formation of thyroxine is catalyzed by a series of manganese compounds.

There have been numerous workers who have demonstrated that certain metals, other than manganese affect the utilization of phosphorus. Cox et al. (1931) using guinea pigs and rabbits found that rations containing soluble aluminum salts in excess of the total phosphorus in the diet produced a severe lowering of the blood phosphorus and bone ash. Ferric salts produced similar but less marked changes. They found that the addition of monosodium phosphate would prevent these changes and concluded that the effects were due to a precipitation of ferric and aluminum phosphates in the intestinal tract. The amounts of aluminum and iron added were 1460 and 2900 ppm., respectively.

Deobald and Elvehjem (1935) added 0.9 percent iron and 0.44 percent aluminum, in the form of soluble salts, to a normal ration for day-old chicks. All chicks developed severe rickets and were dead within three weeks. The addition of monosodium phosphate allowed rapid growth and normal bone formation.

Branion et al. (1931) fed a rachiteogenic ration to rats, after having replaced the calcium carbonate with an equivalent amount of beryllium. The rats fed this ration exhibited bone lesions which were similar to rickets. It was found that a beryllium level as low as 1 percent of the ration would bring about these effects.

Apparently, the amount of manganese which a plant can obtain from the soil is dependent on several factors. Gooden and Grimmett (1928) have shown that lack of drainage tends to increase the manganese content of oats as much as 6 times its level on drained soil. Liming the soil decreased the manganese content of plants. It was also noted that manganese was taken up by the plants more easily than was iron.

Bolin (1934) concluded that the difference in manganese content in different grasses is due to the difference in the capacity of the grasses for extracting manganese from the soil. He found that orchard grass contained 207.5 ppm. of manganese (dry basis). The manganese content ranged downward to 70.1 ppm. for Kentucky bluegrass. Alfalfa contained an average of 46.6 ppm. of manganese. Skinner and Peterson (1928) found that alfalfa hay contained 72 ppm. of manganese, and bluegrass 59 ppm.

EXPERIMENTAL

The following experiment was initiated at the Lake Carl Blackwell Range Area near Stillwater in 1950. Originally, 64 grade Hereford cows were divided into four equal lots, on the basis of age and previous reproductive performance. Two cows were removed from the experiment at the end of the first year; one cow from Lot 3 because of a prolapsed uterus, and one from Lot 4 because of enlarged ovaries and a tumor of the uterus.

During the winter season the cows in all lots were confined to small traps. The winter ration of Lot 1 (control lot) consisted of prairie hay, free-choice, 1.4 pounds of corn gluten meal per head daily, fed on alternate days, and loose salt, free-choice. Corn gluten meal was used because of its relatively low phosphorus content. The cows of Lot 2 were fed the basal ration plus enough manganese sulfate (Techmangam[1]), to supply a total dietary intake of approximately 250 ppm. of manganese. The actual intake of manganese was 1.68 grams per head daily. The cows of Lot 3 were fed the same basal ration plus enough manganese sulfate to provide a daily intake of approximately 500 ppm. of manganese (3.97 grams of manganese per cow daily). Those of Lot 4 received the same treatment as Lot 3, plus enough ferric sulfate and copper sulfate to supply 400 mg. of iron and 40 mg. of copper per head daily. The prairie hay fed to all lots

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[1] Techmangam, a feed grade of manganese sulfate, contained 70 to 72 percent manganese sulfate, 11 percent ammonium sulfate, and 16 to 18 percent magnesium sulfate.

supplied approximately 68 ppm. of manganese, and the level of supplemental manganese represents the difference between 68 and the desired level of manganese. The minerals were mixed with corn gluten meal and fed in a trough throughout the winter period.

The cows in all lots grazed native grass pastures during the summer months. The mineral supplements fed to Lots 2, 3, and 4, were mixed with corn, which was fed at the rate of one pound per head daily, on alternate days. The cows of Lot 1 received one pound of corn per head daily, but received no supplemental minerals. The cows had access to salt at all times.

Bulls were placed with the cows May 1 and were removed in late August. They were rotated among the lots at 14 day intervals during the breeding season to minimize differences in breeding efficiency and heredity. The calves were weaned in October at approximately seven to eight months of age.

Blood samples were taken from one-half the cows of each lot at regular intervals throughout the year for the determination of blood plasma phosphorus, plasma protein, hemoglobin, hematocrit, and red blood cells. Individual cow and calf weights were obtained at the time blood samples were taken. Samples of the four predominant grasses, big bluestem, little bluestem, Indian, and switch, were taken in May, July, and September for determination of dry matter, ash, protein, ether extract, fiber, nitrogen-free extract, calcium, and phosphorus. The chemical composition of the feeds and grasses are presented in Table 1.

RESULTS AND DISCUSSION

Cow Data

Table 2 exhibits the weight data of the cows for both the winter and summer periods. The different treatments had no significant effects upon the weight changes of the cows during the winter period. This is in agreement with data collected the previous year.

During the summer the cows receiving a high level of manganese alone (Lot 3) made very small gains resulting in a yearly weight loss of 90 pounds. The cows of Lots 1, 2, and 4 had average yearly weight gains of 2, 30, and 70 pounds, respectively. The difference in average yearly gain between Lots 3 and 4 was 160 pounds in favor of the Lot 4 cows. If the decreased yearly gain in Lot 3 was due to a high level of manganese, then, possibly the additional iron and copper received by Lot 4 was beneficial. According to Russell (1947), forage produced in areas of northern Scandanavia were found to contain as much as 642 ppm. of manganese. Horses grazing in this area were subject to an anemia, whereas in areas where the manganese levels were normal, anemia was not noted. Iron and copper were added to the ration of Lot 4 to determine the effect of supplemental iron and copper in a high manganese ration. The possibility that the additional iron and copper received by Lot 4 was beneficial would not, however, explain the average yearly gain of only 2 pounds among the cows of Lot 1, which received no additional manganese. In previous work at this station, Nelson et al. (1952)

Table 1. Chemical Composition of Feeds and Grasses, 1951-52

	Percent dry matter	Percent composition of dry matter						
		Ash	Protein	Ether extract	Fiber	N.F.E.	Calcium	Phosphorus
Prairie hay	93.59	8.33	4.13	2.25	34.04	51.25	0.38	0.078
Corn gluten meal[1]	92.12	2.86	43.86	1.33	3.63	48.32	0.13	0.48
Native grass[2]								
May		10.49	13.30	1.20	33.59	41.25	0.41	0.16
July		6.61	4.82	2.11	33.10	53.36	0.33	0.07
September		6.78	5.03	2.01	33.01	53.17	0.32	0.08

[1] An average of two separate lots of corn gluten meal which were fed during the winter.

[2] An average in each case, of the four predominant grasses growing in the general area: Little bluestem, big bluestem, Indian, and switch.

Table 2. Summary of Cow Weight Data, 1951-52

Lot number	Lot 1	Lot 2	Lot 3	Lot 4
Supplemental minerals		250 ppm. manganese	500 ppm. manganese	500 ppm. manganese, iron, and copper
Number of cows per lot	16	16	15	15
Average weight of cows (lbs.)				
Initial 10-24-51	1114	1050	1068	1050
Before calving 1-31-52	1146	1088	1091	1082
End of winter 4-17-52	932	895	889	898
Final 11-4-52	1116	1080	978	1120
Weight gain or loss (lbs.)				
Winter gain to calving	32	38	23	32
Total winter loss	182	155	179	152
Summer gain	184	185	89	222
Yearly gain or loss	2	30	-90	70

found that high levels of manganese supplementation to beef cows resulted in decreased yearly gains. Grummer (1950) reported that the addition of 500 ppm. of manganese to the ration of growing pigs caused a retardation of growth, and decreased appetite.

Blood Data

The results of the blood analyses are shown in Table 3. The plasma phosphorus values were very low during the winter, reaching the lowest value during March at which time they were 3.45, 2.96, 2.42, and 2.94 mg. per 100 ml. of plasma, for Lots 1, 2, 3, and 4, respectively. Maynard (1947), and Huffman (1933) reported that plasma phosphorus levels below 4 mg. percent were indicative of a pending aphosphorosis. However, Knox and coworkers (1941) found that range beef cows remained healthy and reproduced normally when their plasma phosphorus levels dropped as low as 2.00 mg. per 100 ml. of plasma.

During July, the average phosphorus values of the cows in Lots 1, 2, and 4 were 5.18, 4.99, and 6.49 mg. per 100 ml. plasma, respectively, the highest values for the entire summer period. However, phosphorus levels of the cows of Lot 3 remained very low throughout the entire summer. Summer weight gains and plasma phosphorus levels followed a similar trend. Lot 3 cows gained 95 to 133 pounds less than any of the other three lots throughout the summer. It should be pointed out that the cows of Lots 1, 2, and 4, were rotated among three different pastures throughout the summer grazing period, while the cows of Lot 3 remained in the same pasture all summer. However, no variation in the chemical composition of the grasses has been noted among different sections of the range area.

Table 3. Blood Constituents of Cows at Stillwater, October, 1951 to September, 1952

	Oct.	Dec.	Jan.	Mar.	April	June	July	Sept.
Lot	Phosphorus (mg. per 100 ml. plasma)							
1	3.69	3.64	3.03	3.45	2.78	4.96	5.18	5.16
2	3.42	3.30	3.12	2.96	3.00	4.98	4.99	4.63
3	3.60	3.41	2.72	2.42	2.48	3.06	3.29	2.93
4	4.81	4.14	2.78	2.94	2.50	5.24	6.49	5.17
	Hemoglobin (gm. per 100 ml.)							
1	12.1	11.5	11.4	11.3	11.7	11.3	11.9	12.2
2	11.6	10 8	11.0	11.3	11.3	10.9	12.1	12.2
3	11.1	10.0	10.8	11.0	10.8	9.9	10.5	11.4
4	11.4	10.0	10.9	11.8	11.4	11.2	11.6	11.7
	Hematocrit (Volume percent)							
1	38.6	--	--	35.2	32.1	32.6	34.5	36.6
2	36.6	--	--	34.9	31.6	33.1	34.6	36.5
3	36.0	--	--	32.4	31.4	31.6	33.6	35.0
4	36.4	--	--	35.6	31.8	33.6	33.5	35.6
	Plasma protein (gm. per 100 ml.)							
1	9.02	--	--	8.07	8.61	9.03	9.14	9.22
2	8.62	--	--	7.91	8.10	9.05	8.87	8.93
3	8.89	--	--	8.19	8.39	9.07	9.21	8.90
4	8.47	--	--	8.13	8.24	8.90	8.74	8.78
	Red blood cells (millions per cu. mm.)							
1	7.07	6.28	7.10	6.58	6.42	6.67	6.41	6.95
2	6.81	5.94	6.57	6.64	6.16	6.38	6.54	6.93
3	6.76	5.56	6.54	6.20	6.05	5.67	6.13	6.61
4	6.98	5.88	6.63	6.66	6.26	6.61	6.16	6.50

The differences among lots with respect to hemoglobin, hematocrit, plasma protein, and red blood cells were very small and are considered to be insignificant.

Calf Data

A summary of the calf data is given in Table 4. The percent calf crop was reduced in Lot 1 by an open cow, in Lot 3 by an abortion, and in Lot 4 by two abortions. The cows had been Bang's tested, and were apparently free from Bang's disease. It was suggested that the abortions may have been caused by high levels of manganese intake, however, no abortions were observed during the first year of the experiment.

Table 4. Summary of Production Data, 1951-52

Lot number	Lot 1	Lot 2	Lot 3	Lot 4
Number of cows per lot	16	16	15	15
Number of calves weaned per lot	15	16	14	13
Average birth weight of calves (lbs.)	79	72	78	76
Average weaning weight of calves (lbs.)[1]	503[2]	461	490	488

[1] Average weaning weights were corrected for age and sex.

[2] The average weaning weight of Lot 1 calves was significantly higher ($P = < 5$ percent), than the average weaning weight of Lot 2 calves.

Although differences in birth weights were very small among the four lots of calves, those of Lot 1 were 42 pounds heavier than Lot 2 calves at weaning time. This difference was statistically significant. The calves of Lot 1 averaged 13 pounds more at weaning than did Lot 3 calves, and 15 pounds heavier than Lot 4 calves. These differences were not significant. No explanation was apparent as to why the weaning weights of the Lot 1 calves were greater than those of Lot 2. During the previous year the calves of Lot 1 at weaning time, averaged 11 pounds lighter than Lot 2 calves, 14 pounds lighter than Lot 3 calves, and 11 pounds lighter than calves of Lot 4.

SUMMARY

Four lots of grade Hereford cows were fed a basal winter ration consisting of prairie hay, corn gluten meal, and salt. Lot 1 served as the control lot and received only the basal ration. Lot 2 was fed the basal ration with the manganese content raised to 250 ppm. with manganese sulfate. Lot 3 was fed the basal with the manganese content raised to 500 ppm. Lot 4 was fed the same ration and mineral supplement as Lot 3 except that 400 mg. of iron and 40 mg. of copper were fed to each animal daily. During the summer all cows were grazed on native grass pastures, and were fed the mineral supplement mixed with one pound of corn per head daily, while Lot 1 received one pound of corn per cow each day.

1. The cows of Lot 3 had lower plasma phosphorus levels and made considerably smaller gains during the summer grazing season than any of the other three lots.

2. Calves from the cows of Lot 2 had a lower weaning weight than the calves of the other three lots.

3. The weaning weight of the Lot 2 calves was significantly smaller than weaning weights of the calves of Lot 1.

4. Other differences in cow weights, birth weights of the calves, and blood constituents were small.

5. Three of the cows fed 500 ppm. of manganese aborted.

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THESIS TITLE: MINERAL AND MANAGEMENT STUDIES WITH RANGE BEEF CATTLE

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