STUDIES ON

MINERAL AND MANAGEMENT PROBLEMS

WITH BEEF CATTLE IN SOUTHEASTERN OKLAHOMA

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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 several years prior to 1951 reproduction of experimental beef cattle in the Wilburton area of southeast Oklahoma was below normal. The cows appeared to be unthrifty, and showed a definite lack of condition throughout the winter months. The percentage calf crop, weaning weights of calves and subsequent growth of heifers after weaning were also low. There were similar reports of poor performance of beef cattle in southeastern Oklahoma.

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 in excess 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. These indications become more apparent when a comparison was made with a similar trial at Stillwater, Oklahoma. The cows at the Stillwater Station made much larger gains during the summer grazing period than did the Wilburton cows. A higher calving percentage was also noted at the Stillwater Station. The weaning weight of the Wilburton calves was 91 percent lower than that of the calves at Stillwater. Considerable difficulty was experienced with death losses at the 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 the Wilburton cows.

The primary differences in the two experiments were the initial weights of the cows and the forages fed to each group. At the beginning of the experiment the Stillwater cows had a slight weight advantage over the Wilburton cows. Both groups were fed 1.25 pounds of corn gluten meal per head daily plus prairie hay free-choice during the winter feeding period. Each group grazed in its respective area and received prairie hay grown from that locality.

There were several suggested causes regarding 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 during the summer months, due to low bone meal consumption, and a deficiency of phosphorus in the forage. The experiment reported in Part I 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

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

In the absence of sufficient phosphorus the body stores of cattle are depleted, and aphosphorosis occurs. Aphosphorosis symptoms were produced experimentally in dairy cows by Eckles et al. (1932). A ration supplying 0.9 grams 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 plasma. Supplementation with phosphorus resulted in a return to high plasma levels in all cases, usually within 15 to 20 days. A decrease in milk production and a reduction in the percentage of bone ash in the skeleton was observed when a phosphorus deficient ration was fed. Normal calcium values were observed throughout the entire period.

Black et al. (1943) observed that in some areas of Texas cattle appeared stiff, weak, and emaciated and were called "creeps". This condition was later associated with a phosphorus deficiency. Several phosphorus supplements were used and some 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 disodium phosphate in self-feeders from 1945 to 1946. 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. Although satisfactory results were obtained from the other phosphorus supplemental groups, the intake of phosphorus was variable and some mild cases of a deficiency were noted.

Black and associates (1943) in an earlier experiment on the King Ranch in South Texas, used four groups of crossbred cattle. Group 1 served as the untreated control group. Cattle of Group 2 were fed 6.5 grams of phosphorus per head per day as bone meal for dry cows and heifers, and 14.3 grams per day for lactating cows. Group 3 received 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 in each of the 3 lots resulted in heavier calves at weaning, a larger calf crop, and better condition of the cows.

Knox and associates (1941) found that cattle fed a phosphorus supplement on native pastures of New Mexico produced 80 pounds heavier calves at weaning than non-supplemented cows.. The forage contained 0.048 per cent to 0.136 per cent phosphorus and the cows received 2 to 3 grams of supplemental phosphorus per head daily.

Nelson et al. (1951) fed dicalcium phosphate as a phosphorus supplement to a ration deficient in phosphorus. The total daily intake of phosphorus during the winter was approximately 7.6 grams 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. No differences were observed in the cows or calves between the medium and high level of phosphorus intake. Nance (1952) recommended a daily dietary intake of 1.5 grams per 100 pounds of body weight for range cows.

A daily dietary intake of 10 to 12 grams of phosphorus for dairy cattle from 18 months of age to time of calving was considered an adequate amount for maintenance, growth and proper development of the fetus, according to Huffman et al. (1933).

Many workers have observed that a deficiency of phosphorus may be the cause of various kinds of breeding trouble. Jordan and coworkers (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 associates (1926) observed that in certain sections of Minnesota dairy cows were suffering from a phosphorus deficiency. The cows were producing calves at the rate of one every two years. These workers returned practically all the cows to normal breeding habits and optimum milk production by feeding bone meal at the level of two per cent of the ration. Theiler (1928) found only 51 per cent of a group of cows fed no phosphorus supplement calved normally, while 80 percent of the cows fed bone meal calved normally on pastures of the Union of South Africa. Lantow (1932) reported cows fed supplemental phosphorus matured earlier, produced larger calf crops, had lower death rates, and produced heavier calves at weaning, than non-supplemented cows at the New Mexico Experiment Station.

Several investigators have observed 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 associates (1936) observed 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 the the literature, a wide range of plasma phosphorus levels may be considered normal. Inorganic phosphorus levels of the blood usually range between 4 and 9 mg. per 100 ml. of plasma depending upon the age and species, according to Maynard (1947). 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 for the bovine according to Dukes (1947) is 2.3 to 9.6 mg. per cent. Loosli et al. (1950) concluded from their experiments that normal inorganic phosphorus values for cows were 4 to 6 mg. per cent, and for calves under one year, 6 to 8 mg. per cent of the plasma.

Palmer (1930) stated that the average inorganic phosphorus level was 4.87 mg. for mature cows, and 7.56 mg. 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. Moxon (1947) determined inorganic plasma phosphorus levels of 88 range cattle over a period of five years. The levels ranged from 1.19 to 9.57 mg. per 100 ml. plasma, with a mean value of 4.77 mg. per cent.

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 could be easily controlled by placing the phosphorus supplements in the drinking water supply. Tash et al. (1947) stated 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 mineral requirements of the animal body include iron, copper, iodine, manganese, zinc, and cobalt. Since these elements are required only in very small amounts, they are known as trace minerals. They must be present in adequate amounts to maintain normal body functions. Deficiency symptoms of some of the trace minerals occur occasionally under practical conditions and can be produced experimentally, but exact quantitative requirements are still not definitely known. All of the deficient areas and the value of mineral supplementation in these deficient areas also are not definitely known.

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. Chappel *et al.* (1952) found that adding a synthetic alfalfa ash to a ground corn cob basal ration improved digestion of organic matter and crude fiber, but the results were less favorable than those obtained from natural alfalfa ash. A mineral mix including sodium chloride, potassium chloride, manganese, zinc, iron and copper failed to improve the digestibility of any ration constituent.

Plumlee and coworkers (1953) conducted two experiments with identical twin calves to determine the value of trace mineral additions to a ration of ground corn cobs and Purdue Supplement A. Five sets of identical twins were used. One individual of each set received the basal ration with no trace minerals; one calf in each of two sets received the basal ration plus all the trace minerals except magnesium; magnesium and iron; magnesium iron and manganese, respectively. Feeding trace minerals depressed the appetite and therefore limited the intake of cobs. In ad libitum feeding the twins receiving trace minerals at less cobs and grew at a slower rate.

Bentley and Moxon (1952) compared alfalfa ash, a trace mineral mix, (cobalt, zinc, manganese, copper, and iron), and reduced iron as supplements 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 the trace mineral mix improved the average daily gain by 43 per cent, whereas the iron supplement alone had no effect on growth performance or feed efficiency of the steers. 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.

Nelson and associates (1951) added iron, cobalt, iodine copper and manganese in one of two years to a ration of prairie hay and corn gluten meal in winter and native grass range in summer for weanling heifers. They reported no difference in gain or appearance after two years' work. Three years of work with yearling and two-year-old steers being fattened on grass was summarized by Pope and coworkers (1953). No beneficial effect was noted by using a trace mineral mix containing cobalt, manganese, zinc, copper, and iron. Nelson (1952) found no beneficial effects by adding a trace mineral supplement to the winter ration for stocker cows in north central Oklahoma.

Noland et al. (1951) found that the addition of the trace minerals cobalt, copper, iron, and manganese increased gains and feed efficiency in growing swine, although the degree of response varied somewhat between experiments. Speer and coworkers (1952) added a mineral mix containing iron, copper, 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 et al. (1949) found that supplementary cobalt, iron, copper, and manganese improved both growth and feed efficiency in growing swine.

Pierce (1954) found that trace mineral salt in the growing-fattening ration had no measurable effects on the chemical composition of the carcass of 200-pound hogs.

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 Haemonchus contortus 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 (1921a) reported the presence of the stomach worm in the abomasum of cattle and sheep examined in local slaughterhouse. Cases of Strongytosis, caused by O. ostertagi were reported by Ackert and Muldoon (1920) 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. According to Veglia (1915) 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) stated that freezing did not affect the larvae.

Porter and Cauthen (1946) stated that the larvae undergo two molts after entering the animals body and then enter the gastric pits and fundic glands of the abomasum. There they mature and localize in the pyloric region as adults. Eggs are usually found in the feces 19 to 31 days after the larvae are swallowed.

According to Porter (1942) the most common symptoms of stomach worm infestation are: loss of flesh, general weakness, anemia, edema of the lower jaw, and diarrhea. Clunies Ross (1933) infected lambs with stomach worms experimentally 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. Two of the lambs died of parasitism. It was concluded that the anemia of the infected lambs was due to gastric hemorrhage alone. Martin and Clunies Ross (1934) estimated that 2,000 female stomach worms could withdraw about 30 cc. of blood in twenty-four hours from a host animal. That amount did not include blood removed by the male worms. Blood actually passing through the bodies of hook worms imbedded in the intestinal mucosa of a dog was observed by Wells (1931). Animals with extreme infection showed little evidence of ill health, according to Clunies Ross (1936), when they were receiving satisfactory feed.

Vegors et al. (1953) studied the effect of heavily infested yearling beef calves, on three types of winter pastures with corn supplementation. The calves were allowed to graze on temporary pasture of rye grass, oats, and crimson clover pasture. Half the calves on each pasture were supplemented with corn. The corn supplemented calves had only one-fourth as many parasites as did non-supplemented calves. The three most prevalent parasites found in the calves on autopsy, were C. punctata, O. ostertagi and T. axei. According to Taylor (1934) lambs receiving a full feed of hay and concentrates contained fewer worms at autopsy than did lambs fed a ration of hay alone.

Richard and coworkers (1954) reported lambs infected with Haemonchus contortus, had a depressed blood hemoglobin level, and growth was retarded. The anemia was less severe and weight gains were better in the case of lambs which received trace minerals plus steamed bone meal. Increasing the protein, with or without minerals, appeared to be of little value in increasing the resistance to stomach worm infection.

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 infested calves were resistant to reinfection, while the others were readily infested. Foster and Cort (1931, 1932, 1935) found dogs resistant to reinfection when they were fed a good diet, but the same dogs fed a poor diet were very susceptible to reinfection.

Most species of stomach and intestinal worms of cattle are also present in other ruminants. Tetley (1953) observed that lambs, grazed on pasture previously occupied only by cattle, acquired Ostertagia ostertagi; Cooperia punctata; and Cooperia oncophora, species of roundworms ordinarily found in cattle. He concluded that cattle would contribute parasites to sheep is these animals were grazed together or if sheep followed cattle on pastures, although, Snell (1936) had previously reported a beneficial effect from grazing the two species together. Trichostrongylus axei has been observed by Stoll (1936) and Taylor (1937) in horses, cattle, sheep, and other ruminants. Cooperids, a group of intestinal worms common to sheep, has been observed in cattle and goats. (Dikmans, 1939; Ransom, 1920; and Edgar, 1936).

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. Verninous gastritis, caused by O. ostertagi, has been noted among cattle in Texas by Barger (1927). Occuring among yearling cattle, O. ostertagi caused anemia, emaciation, rough haircoat, diarrhea, bottlejaw, and even death. O. ostertagi was described by Porter (1942) 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.

Porter (1942) described Trichostrongylus axei, another of the roundworms, as being very slender and only about one-fifth of an inch long.

Carbon tetrachloride was one of the first chemicals used in controlling internal parasites. 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 et al. (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. Phenothiazine was compared to copper sulfate and nicotine sulfate by Shorb et al. (1941) 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.

Thorp (1943) and Willman (1943) recommended a phenothiazine drench for sheep in the spring and fall, with a salt-phenothiazine mixture during the summer. Peterson (1943) found that a one to fourteen phenothiazine-salt mixture for lambs and ewes 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 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 twelve and one-half 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 alone.

Weir and coworkers (1948) added soybean meal, trace minerals, and bone meal separately and together to a basal ration of mixed grass and legume hay and corn for lambs. It was noted that there were more worms in the sheep that received trace minerals. These workers stated that, "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 (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.

Cauthen (1953) reported doses of 50 gms. and 60 gms. of phenothiazine for yearlings are not large enough to remove a satisfactory per centage of O. ostertagi but was satisfactory for removing T. axei Larger doses of 125 gms. removed a much greater per cent of O. ostertagi and produced only transitory toxic effects of extreme sluggishness during the twenty-four hours following the treatment. Levine et al.

(1954) found that modification of the phenothiazine molecule has varying effects upon the toxicity of the compounds produced.

Baker and coworkers (1954) found phenothiazine to be ineffective against O. ostertagi in lambs at the university of California. Swanson et al. (1954) reported that phenothiazine when given to normal, healthy, unweaned, beef-type calves carrying a light parasite load had no influence on daily gain.

The variation in 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.

Grinnells (1950) reported calves (6 to 12 months) in parasite infected areas contained 4 million worm eggs in their feces per calf daily, while cows five years or older contained only small infestation.

The administration of free-choice phenothiazine gives considerable protection against heavy onslaughts of intestinal wire worms and stomach worms in sheep, according to Richards (1953).

According to Price (1953) a free-choice 1:9 phenothiazine-salt mixture satisfactorily controlled H. contortus in range sheep over a period of five to seven years.

Foster (1953) administered phenothiazine orally at the rate of 0.5 gm. phenothiazine daily per 100 pounds of body weight up to a total dose of 2 to 5 gm. per head daily for animals over 500 pounds for adequate control of Haemonchus, Bunostomum, and Oesophagostomum.

Cauthen (1953) reported small daily doses of 1.5 to 2.0 gms. of phenothiazine are satisfactory for controlling *Ostertagia*, *Trichostrongylus*, and *Cooperia*.

SHADE

Heat is being produced constantly in the body as a result of physiological oxidation. There must, therefore, be some provision for insuring a constant heat loss. Dukes (1947) stated that 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. The point of hyperthermal rise is defined by Dukes (1947) as the environmental temperature at which physical mechanisms of heat dissipation fail to maintain a constant body temperature.

Rhoad (1936) found temperatures in excess of 85 degrees Fahrenheit to have a marked detrimental effect upon production and feed utilization in cattle.

Kibler et al. (1949) reported that dairy cattle decreased heat production from 30 to 40 per cent when the ambient temperature rose from 80 to 100 degrees F. Part of this was due to lowered feed consumption and lowered milk production. Regan (1938) noted that several changes occurred in the composition of milk when dairy cows were subjected to a temperature of 80 degrees F. Heitman and coworkers (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. Artificial shade was used by Miller et al. (1951) in pastures for dairy cows. The cows spent 63 per cent of their time grazing when the temperatures reached 80 to 85 degrees F. At temperatures of 86 to 91 degrees, the cattle spent only half as much time grazing. The cows spent the rest of the time in the shade. When temperatures reached 97 degrees the cows only spent one-third as much time grazing and the rest was spent under the shade. In another experiment with dairy cows Seath and Miller (1946a) reported that cows grazed only 1.8 hours during the day and 5.7 hours at night when the average daily temperature was 86 degrees. When the average daily temperature dropped to 72 degrees they spent 4.5 hours in the day grazing and 4 hours at night. The animals entered the shades at about 9:20 each morning, and remained until milking time at 3:00 P.M. When the cattle had been under the shade about an hour body temperature began to rise, due to the rising air temperature.

Wood slat, hay covered, aluminum covered, and galvanized covered shades were compared by Kelly and Ittner (1948) 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 shades were 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 sub-roof, 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 evaporator 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 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 ten 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) reported that solid roofed shades reduced radiation by 65 per cent, whereas slat covered shades reduced radiation by 55 per cent.

Seath and Miller (1948a) tied six dairy cows in the sun from noon til 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 front 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 water sprinklers in the pastures for dairy cows. It was noted that body temperatures were reduced from 104.8 to 101.9 degrees F. without the use of the sprinklers, but use of the sprinklers further reduced the temperature to 100.7 degrees. The 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 and shade.

In several similar experiments with swine, Heitman and Hughes (1949) after subjecting hogs to temperatures of 115 degrees F., poured 100 degree water on the floor to determine the time for cooling. The body temperature was reduced two degrees within 90 minutes, and the respiratory rates from 150 to 30 per minute. When air circulation was added, cooling was more rapid. Under the same temperature conditions on a dry floor, no apparent cooling was detected.

Heitman and Hughes (1949) reported that a relative humidity increase from 30 to 94 per cent at 96 degrees F. increased both body temperatures and respiratory rates of swine. However, Tidwell and Fletcher (1951), found the highest respiratory rates of swine occured on days of highest temperature and lowest relative humidity. Lowest respiratory rates occurred on days of lowest temperature and highest humidity. Seath and Miller (1946b) 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.

Although cattle do not have sweat glands, there is some water loss, other than by the respiratory tract or by the feces and urine. Rhoad (1936) stated that 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.

Kibler and Brody (1950) reported that 800 to 900 pound Jersey cows lose 30 pounds of water daily from the surface of their skin when subjected to 80 degrees temperature. 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.

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

Experiments were conducted by Ittner and coworkers (1951), to study the effect of cooling the drinking water to 65 degrees for cattle. They noted that cooling the drinking water lessened the heat load on the cattle about 2,800 B. T. U.'s per day. This is compared to a heat load reduction of 1,344 B. T. U.'s per hour under artificial shade at a temperature of 100 degrees F.

Thompson et al. (1949) reported that Jerseys consumed much more water per 100 pounds body weight than did Brahmans at a temperature of 85 degrees. At temperatures over 85 degrees, there was very little difference in water consumption of the breeds. As the temperature of hogs increased, water consumption decreased according to Heitman and Hughes (1949).

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. More than 150 cows, heifers, and steers of various breeds and crosses were tested by Rhoad (1942), at the Jeanerette Experiment Station in Louisiana 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. The dairy breeds range somewhere between 73 and 93. A slightly different formula was used by Gaalaas (1947); HT = 100-14 (BT - 101). He noted very little yearly variation in heat tolerance of a herd, and no difference with respect to gestation and lactation, sire or dam.

Berousek and Nelson (1950) used temperature-controlled and open-front artificial shelters to study the comparative effects of different artificial shelters on dairy herd performance during hot weather. The cows were rotated every ten days and given free access to the artificial shelter or the natural shade in each pasture. On the average, each lot spent only one-half hour per day under the artificial shelter but spent several hours under the natural shade trees. Milk production records for the two herds showed no effects from access to either of the artificial shelters.

EXPERIMENTAL

The following experiment was started in the fall of 1951 at the Range Cattle Mineral Station at Wilburton, Oklahoma. The second year's work (Nov. 1952 - Nov. 1953) is summarized here, however, essentially the same procedure was followed both years. Originally sixty two-year-old grade Hereford heifers were divided into six lots of 10 head each. Five heifers of each lot were obtained from a commercial herd in southern Oklahoma, the other five of each lot were from the grade herd at Stillwater. Each year, the cattle had access to native grass pasture year-long and received no other roughage at anytime. For simplicity of presentation, the experimental phase is divided into two periods, a wintering period and a summer period.

During the winter, the cows of all lots were fed 2.5 pounds of cottonseed cake per head daily and sufficient bonemeal to supply approximately 10 grams of supplemental phosphorus per cow daily. The bonemeal was fed on the cake, and salt was offered free-choice to all lots.

A summary of the experimental procedure is presented in Table I. 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 metal tanks, and approximately 3.63 grams of monosodium phosphate was added to each gallon of water, supplying approximately 0.9 grams 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 following trace minerals: iron, copper, cobalt, and iodine. The trace minerals were mixed with salt and offered free-choice in the summer and fed on the cottonseed cake in the winter.

Table I. Summary of the Experimental Design

Treatment	Lot Number					
	1	2	3	4	5	6
Shade	No	No	No	Shade	Shade	Shade
Phosphorus in drinking water	No	Yes	Yes	No	Yes	Yes
Bone meal and Salt	Yes	No	No	Yes	No	No
Trace Minerals	No	No	Yes	No	No	Yes
Phenothiazine[1]	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$

[1]One-half of the cows and their calves in each lot were treated with phenothiazine.

Therefore, the actual nutritional treatment of Lot 1 was the same as Lot 4, Lot 2 same as Lot 5, and Lot 3 same as Lot 6. However, Lots 4, 5, and 6 were provided with artificial shade in 1952-53. In the preceeding year Lots 1, 2, and 3 had access to shade and Lots 4, 5, and 6 did not.

To determine the value of parasite control one-half of the cows and calves in each Lot were drenched with phenothiazine. The cows were treated for parasites four times at approximately two-month intervals beginning January 29. Each cow received 62.5 grams of phenothiazine per dose. Calves were treated three times at approximately six-week intervals beginning June 2. The initial dosage was 12.5 grams, the second was 25 grams and the third was 37.5 grams of phenothiazine per calf. Fecal samples were taken from the cows and calves at weaning time, October 15, and examined from worm eggs.

Cows were pasture-bred to purebred Hereford bulls. The bulls were placed with the cows on May 1 and were removed September 1. To minimize differences due to heredity and breeding efficiency the bulls were rotated among lots each weigh date. The average calving date was in March, and the calves were weaned October 15.

Each of the lots of cows was rotated among pastures at each weigh date throughout the year. Each pasture contained an artificial shade and Lots 4, 5, and 6 had access to artificial shade throughout the summer period.

Blood samples were taken from the jugular vein of one-half of the cows in each lost six times, at one- or two-month intervals throughout the year for the determination of blood plasma phosphorus, hemoglobin, and red blood cells.

Grass samples were taken in November, December, February, March, May, July and September for chemical analyses of ash, ether extract, nitrogen-free extract, calcium, phosphorus, and protein. Each sample was a composite of the three predominant grasses, big bluestem, little bluestem and Indian, obtained equally from the six pastures. Samples of the cottonseed cake and bone meal were also collected for chemical analyses.

RESULTS AND DISCUSSION

Grass and Feed Analyses

The results of the chemical analyses of the grasses and feeds are presented in Table II. The protein and phosphorus levels of the grasses were highest in May. The protein decreased in July, increased slightly in September and rapidly decreased as the plants matured and, like phosphorus, reached its lowest levels during the winter season. The chemical composition of the grasses has been very similar the past three years.

Table II. Chemical Composition of Feed and Grasses

		Percent composition of dry matter						
		Ash	Prot.	Ether Extract	Fiber	N.F.E.	Ca.	Phos.
Cottonseed Cake		6.58	45.50	5.13	9.31	33.48	0.24	1.15
Bone Meal		89.72	4.73	----	----	5.55	32.88	15.41
Grasses[1]								
Nov.	1952	6.21	3.19	1.53	33.62	55.45	0.30	0.032
Dec.	1952	7.20	2.82	1.31	33.22	55.45	0.30	0.028
Feb.	1953	7.06	2.93	2.26	35.30	52.45	0.30	0.025
March	1953	8.31	3.68	1.58	35.55	50.88	0.29	0.030
May	1953	7.03	9.18	1.75	32.49	49.55	0.27	0.152
July	1953	6.00	4.94	3.36	34.85	50.85	0.38	0.068
Sept.	1953	7.14	6.21	2.98	34.03	48.64	0.34	0.078

[1]Composite grass sample of the three predominant grasses, big bluestem, little bluestem, and Indian.

Phosphorus in Drinking Water

The supplemental phosphorus intake of the cattle by lots is shown in Table III. It can be seen that the daily supplemental phosphorus intake during the summer was approximately 10 grams per cow in lots with phorphorus in the drinking water while those fed phosphorus in the salt-bone meal mixture consumed only 2.26 grams per day.

Table III. Supplemental Phosphorus Intake, (gms. per cow daily)[1]

Lot number	1	2	3	4	5	6
Winter (from bone meal)	10.01	10.01	10.01	10.01	10.01	10.01
(from cottonseed cake)	13.05	13.05	13.05	13.05	13.05	13.05
Summer	2.19	10.09	9.32	2.34	9.70	9.02

[1]These amounts are in addition to the phosphorus obtained from pasture forage.

A summary of the production and weight data of the cows by lots is presented in Table IV. The cows that received phosphorus in the water (Lots 2 and 5) made slightly larger summer and yearly gains than cows with access to a mineral mix of 2 parts salt and 1 part bone meal (Lots 1 and 4).

There was no apparent difference in average birth weight of the calves or per cent of calf crop due to differences in treatments. The weaning weights of the calves in Lots 2 and 5 were slightly larger than those of Lots 1 and 4. This difference was accounted for largely by the relatively low weaning weight of the lot 4 calves.

A summary of the blood constituents is presented in Table V. There was some tendency for the cows with a low summer phosphorus intake (Lots 1 and 4) to have a slightly lower plasma phosphorus level during late summer than cows receiving high phosphorus levels.

Table IV. Performance of Cows and Calves at Wilburton

	No shade in summer			Artificial shade in summer		
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
	Bone meal and salt	Phosphorus in water	Phosphorus in water, Trace minerals	Bone meal and salt	Phosphorus in water	Phosphorus in water, Trace minerals
Number of cows per lot	10	9[1]	10	10	10	10
Average weight of cows (lbs.)						
Initial 11-7-52	894	913	942	898	895	886
Before calving 1-29-53	884	903	921	910	874	884
End of winter 4-10-53	838	882	864	899	846	854
Final 11-12-53	969	1028	1050	1036	1020	1049
Weight gain or loss (lbs.)						
Winter loss to calving	--10	--10	--21	+12	--21	--2
Total winter loss	--56	--31	--78	+1	--49	--32
Summer gain	131	146	186	137	174	195
Yearly gain	75	115	108	138	125	163
Average birth weight of calves (lbs.)[2]	71	64	70	67	67	69
Number of calves weaned	10	8	9	9	10	9
Average weaning weight of calves (lbs.)[3]	456	458	455	435	458	460

[1]One heifer in Lot 2 died at calving during the first year.

[2]Corrected for sex by adding 5 lbs. to the actual birth weight of each heifer.

[3]Corrected for age by adjusting all calves to a standard age of 210 days and for sex by adding 25 lbs. to the age corrected weight of each heifer.

This agrees with results obtained the previous year (Blucker, 1953). During winter feeding of cottonseed cake and bone meal the plasma phosphorus values were high in all lots. The higher intake of phosphorus by Lots 2 and 5 apparently had no effect upon plasma phosphorus value until the phosphorus content of the forage had decreased during late summer. There were no significant differences in hemoglobin or red blood cell count between the treatments.

Table V. Blood Constituents of Cows

LOT	11-7-52	12-31-52	3-9-53	4-10-53	7-30-53	9-1-53	11-12-53
			Phosphorus (Mg. per 100 ml. plasma)				
1	5.25	7.96	7.42	6.31	3.78	3.72	2.37
2	5.27	6.63	6.57	5.81	4.46	5.05	4.36
3	5.64	6.62	6.38	5.84	4.66	5.42	3.88
4	4.20	6.54	6.34	5.58	3.84	4.43	4.10
5	5.71	5.77	6.54	5.99	3.87	5.81	4.33
6	5.13	6.03	6.38	6.56	4.62	5.60	4.10
			Hemoglobin (gm. per 100 ml.)				
1	12.4	12.9	12.42	11.58	12.24	11.16	13.4
2	12.6	11.12	12.68	11.54	11.92	11.84	12.06
3	12.6	12.03	11.40	11.76	12.80	11.86	13.86
4	13.2	11.80	12.2	11.8	12.4	11.38	13.02
5	12.2	14.0	12.5	11.9	12.5	12.0	12.84
6	12.1	12.4	11.8	11.5	12.0	11.2	13.22
			Red Blood Cells (Millions per cu. mm.)				
1	8.96	8.26	7.40	7.22	7.47	6.80	7.65
2	8.32	7.09	7.47	6.82	7.32	7.12	7.13
3	7.64	7.64	6.80	6.99	7.84	7.27	8.07
4	8.76	7.33	7.50	6.86	7.44	6.68	7.60
5	7.01	8.85	7.70	6.85	7.50	7.17	7.34
6	8.75	8.06	7.34	6.53	7.41	6.72	7.57

The cows apparently received an adequate amount of phosphorus in the summer forage, making any additional intake of phosphorus in drinking water of very small apparent value. It is also possible that the storage of phosphorus during the winter period was sufficient to maintain adequate phosphorus levels in the body throughout the summer. Calving dates the second year as compared to the first indicated that the high phosphorus cows rebred more readily than the low phosphorus cows. This trend will have to be observed in succeeding years to be of any significance.

Trace Minerals

The actual daily intake of supplemental trace minerals for Lots 3 and 6 is shown in Table VI. The average yearly weight gain (Table IV) 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 cows receiving phosphorus in drinking water without trace minerals (Lots 2 and 5). Although this difference was not significant ($P < 5$ per cent), it is in agreement with and larger than a similar difference observed in the previous years work by Blucker, (1953). Futher results must be obtained before it can be concluded that trace minerals are beneficial to the cows.

Table VI. Intake of Supplemental Trace Minerals, (mgs. per cow daily)

Trace Mineral:	Iron	Copper	Iodine	Cobalt
Winter (Hand-fed)				
Lots 3 and 6	90	9	1.8	1.8
Summer (In salt)				
Lot 3	66.00	6.60	1.32	1.32
Lot 6	59.33	5.93	1.18	1.18

The feeding of trace minerals to the cows had no apparent influence on the weaning weight of the calves or in the per cent calf crop. The previous year Blucker (1953) found that calves from the cows fed trace minerals averaged 23 pounds heavier at weaning than calves from cows without supplemental trace minerals in the ration. The lack of a consistent effect from the feeding of trace minerals is in agreement with results obtained by Nelson (1952) who failed to obtain beneficial results by feeding a similar trace mineral mixture to growing heifers at Wilburton.

Parasite Control

A summary of the production and weight data for the parasite control phase of the experiment is presented in Table VII. 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 14 pounds more per head than the untreated cows. This is in agreement with results reported by Blucker (1953), who also found that treated cows gained only slightly more than untreated cows.

There were no apparent differences in per cent calf crop and birth weight of calves when treated and untreated groups were compared.

The untreated calves had a 16 pound larger average weaning weight than the treated calves. Blucker (1953) the previous year found a smaller difference in favor of the untreated calves. Differences both years were not statistically significant.

There have been no reports in the literature of phenothiazine producing harmful effects when administered to livestock at recommended levels, so it could not be concluded from the small differences observed in this experiment that phenothiazine was toxic to calves.

Table VII. The Effect of Parasite Control on Cows and Calves.

	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 11-7-52	925	883
End of winter 4-10-53	870	843
Final 11-12-53	1053	997
Winter loss (lbs.)	--55	--40
Summer gain (lbs.)	183	154
Yearly gain (lbs.)	128	114
Average birth weight of calves (lbs.)[1]	71	72
Number of calves weaned	27	28
Average weaning weight of calves (lbs.)[2]	446	462

[1]Corrected for sex by adding 5 lbs. to the actual birth weight of each heifer.

[2]Corrected for age by adjusting all calves to a standard age of 210 days and for sex by adding 25 lbs. to the age-corrected weight of each heifer.

Fecal samples were taken from the cows and calves in October, and only a slight infestation among all cattle was indicated by the egg count. Provided the infestation was not heavy enough in any of the cattle to visibly affect health and general appearance, or decrease gains in the cows and calves, drenching with phenothiazine would not be expected to produce beneficial effects on the weight gains of cows or on the growth and thriftness of calves. The primary benefits of treating with phenothiazine would be expected in the increased weaning weights of calves, according to Grennels (1950), who found that calves (6 to 12 months) in parasite infested areas contained 4 million worm eggs per calf daily in their feces, while cows five years old or older were only lightly infested.

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

Artificial Summer Shade

The results of the summer shade phase of the experiment summarized in Table VIII. There was no appreciable difference in summer gain between cows with and without summer shade. The previous year cows with artificial shade averaged 25 pounds per head heavier during the summer period than the cows without shade (Blucker, 1953).

Table VIII. The Effect of Summer Shade on Cows and Calves.

	Summer shade (Lots 4, 5, and 6)	No summer shade (Lots 1, 2, and 3)
Number of cows	30	29
Average weight per cow (lbs.)		
Initial 11-7-52	893	916
End of winter 4-10-53	866	847
Final 11-12-53	1035	1015
Average birth weight of calves (lbs.)[1]	71	72
Number of calves weaned	28	27
Average weaning weight of calves (lbs.)[2]	451	456

[1]Corrected for sex by adding 5 lbs. to the actual birth weight of each heifer.

[2]Corrected for age by adjusting all calves to a standard age of 210 days and for sex by adding 25 lbs. to the age-corrected weight of each heifer.

Differences in per cent calf crop and average birth weight of the calves were small and probably not related to difference in treatment. The calves without shade had an average weaning weight of 456 pounds, compared to 451 pounds for the calves with shade. Blucker (1953) the previous year found a significant difference of 18 pounds in favor of the calves which received no artificial summer shade. It is possible that the calves without shade spend more time grazing than calves with access to shade.

Differences in both cow and calf weights have been small. However, a possible beneficial effect of shade for mature cows, with little value for calves, is suggested by the work of Seath (1948), who reported that two yearling dairy heifers subjected to an average daily temperature of 90 degrees F. had lower respiration rates and body temperature, spent more time grazing, and less time under the shade than did older dairy cows.

SUMMARY

An experiment was initiated at the Range Cattle Minerals Station near Wilburton, Oklahoma, in the fall of 1951. The second year's work is summarized here. Originally, sixty 2-year-old grade Hereford heifers were divided into six equal lots. All the cows were subjected to range conditions and had access to native grass pasture year long.

During the winter, all cows were fed bone meal and 2.5 pounds of cottonseed cake per head daily. Salt was offered free choice to all lots. Lots 3 and 6, in addition to bone meal, and cottonseed cake received the trace minerals, iron, copper, cobalt, and iodine.

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

The results may be summarized as follows:

1. The cows fed bone meal free-choice in a salt-bone meal mixture during the summer consumed only 2.26 grams of phosphorus per cow daily as compared to 10 grams per head daily for the cows receiving monosodium phosphate force fed in the drinking water. The additional

phosphorus intake during the summer was of no great benefit either to the cows or calves.

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

3. There were no apparent differences in the performance of cows treated for internal parasites and those not treated. However, the untreated calves had an average weaning weight 16 pounds heavier than the treated calves. A determination of the number of eggs present in the feces indicated only a mild infestation in both the treated and untreated cows.

4. There was no appreciable difference in the summer gain between cows or between calves with and without artificial summer shade.

LITERATURE CITED

Ackert, J. E. and W. E. Muldoon. 1920. Strongylosis (Ostertagia) in cattle. Am. Vet. Med. Assoc. J. 58:138.

Allcroft, Ruth and W. H. Parker. 1949. Hypocupraemia in dairy cows. Brit. J. Nutr. 3:vii.

Andrews, John S. 1939. Life history of the nematode, Cooperia curticei and development of resistance in sheep. J. Agr. Res. 58:771.

Andrews, John S. 1942. Stomach worm (Haemonchus contortus) infection in lambs and its relation to gastric hemorrhage and general pathology. J. Agr. Res. 65:1.

Andrews, F. N., C. L. Shrewsbury, C. Harper, C. M. Vestal and L. P. Doyle. 1948. Iodine deficiency in newborn sheep and swine. J. An. Sci. 7:298.

Baker, Donald W. 1939. A new system of anthelmintic control for gastro-intestinal parasites of ruminants. Cornell Vet. 29:192.

Barger, E. H. 1927. Ostertagia ostertagi in California cattle, with $CuSO_4$ as apparently successful therapeutic. Am. Vet. Med. Assoc. J. 71:560.

Becker, D. E. and S. E. Smith. 1951. Metabolism of cobalt in lambs. J. Nutr. 43:87.

Bekker, J. G. 1932. Studies in mineral metabolism. XXIV "On the administration of phosphorus to animals through their drinking water supply." 18th Rept. of the Dir. of Vet. Services and An. Ind. of S. Africa. p. 751.

Bentley, O. G. and A. L. Moxon. 1952. A semi-synthetic ration for studying the trace element requirements of cattle. J. An. Sci. 11:756.

Bentley, O. G., M. Moinuddin, E. W. Klosterman and A. L. Moxon. 1954. The effect of trace minerals on growth performance and vitamin B_{12} synthesis of steers. J. An. Sci. 13:789.

Berousek, E. R. and G. L. Nelson. 1950. Dairy cattle loafing barns designed for summer temperature control. Agr. Engr. 33:290.

Black, W. H., L. H. Tash, J. M. Jones and R. J. Kleberg, Jr. 1943. Effects of phosphorus supplements on cattle grazing on range deficient in this mineral. U. S. D. A. Tech. Bul. 856.

Blucker, J. D. 1953. Mineral and management studies with range beef cattle. Master of Science Thesis, Oklahoma A. and M. College.

Britton, J. W. 1944. Phenothiazine in cattle practice. Vet. Med. 39:239.

Brock, W. E., C.C. Pearson and I. O. Kliewer. 1953. Daily minimal dosage of phenothiazine in control of nematode infections in cattle. Proc. 89th Annual Meeting (1952) Am. Vet. Med. Assoc. 167.

Brody, Samuel. 1946. Physiological background for psychroenergetic studies. Agr. Engr. 27:514.

Burroughs, Wise, H. G. Headley, R. M. Bethke and P. Gerlaugh. 1950a. Cellulose digestion in good and poor quality roughages using an artificial rumen. J. An. Sci. 9:513.

Burroughs, Wise, N. W. Frank, P. Gerlaugh and R. M. Bethke. 1950b. Preliminary observations upon factors influencing cellulose digestion by rumen microorganisms. J. Nutr. 40:9.

Burroughs, Wise, A. Latona, P. DePaul, P. Gerlaugh and R. M. Bethke. 1951. Mineral influences upon urea utilization and cellulose digestion by rumen microorganisms using the artificial rumen technique. J. An. Sci. 10:693.

Carpenter, L. E. 1947. The copper requirements of swine. Hormel Inst. of the Univ. of Minn. Ann. Rept., p. 19.

Carpenter, L. E. 1948. The copper requirements of swine. Hormel Inst. of the Univ. of Minn. Ann. Rept., p. 21.

Carpenter, L. E. 1949. The copper requirements of swine. Hormel Inst. of the Univ. of Minn. Ann. Rept., p. 23.

Carroll, W. E., H. H. Mitchell and G. E. Hunt. 1930. KI as a mineral supplement in paired feeding experiments with growing swine. J. Agr. Res. 41:65.

Cauthen, G. E. 1953. The effect of small daily doses of phenothiazine on the development of larvae of the gastro-intestinal parasites of cattle. Am. J. Vet. Res. 14:30.

Chamberlain, C. C., G. A. Branaman, L. H. Blakeslee, R. H. Nelson and F. T. Thorp. 1948. Some effects of cobalt in sheep rations. J. An. Sci. 7:3.

Chappel, C. F., R. J. Sirney, C. K. Whitehair and Robert MacVicar. 1952. The effect of minerals on digestion of low quality roughage. J. An. Sci. 11:4.

Chase, M. S., C. J. Bubler, G. E. Cartwright, and M. M. Wintrobe. 1952. Studies on copper metabolism. II The influence of copper on the absorption of iron. J. Biol. Chem. 199:757

Clunies Ross, I. 1931. The host specificity of H. contortus of sheep and cattle. Aust. J. Exp. Biol. and Med. Sci. 8:217.

Clunies Ross, I. and H. Gordon. 1933. Nutritional factors affecting resistance to Haemonchosis. Aust. Vet. J. 9:100.

Clunies Ross, I. and H. Gordon. 1936. The internal parasites and parasitic diseases of sheep, their treatment and control. 223 pp. Sydney, Australia.

Comar, C. L., G. K. Davies and R. F. Taylor. 1946. Cobalt metabolism studies, radio-active cobalt procedures with rats and cattle. Arch. Biochem. 9:149.

Cunningham, I. J. 1931. Some biochemical and physiological aspects of copper in animal nutrition. Biochem. J. 25:1267.

Dempsey, E. W. and E. B. Astwood. 1943. Determination of rate of thyroid hormone secretion at various environmental temperatures. Endo. 32:809.

Dikmans, Gerard. 1921a. Preliminary notes on parasites found in ruminants at the municipal Abattoir, Baton Rouge, La., La. Tech. Bul. 186:1.

Dikmans, Gerard. 1921b. Preliminary report on parasites found in ruminants at the municipal Abattoir, Baton Rouge, La., La. Tech. Bul. 186:16.

Dikmans, Gerard. 1939. Parasitic enteritis in calves. Vet. Med. 34:28.

Dinusson, W. E., E. W. Klosterman, E. L. Lasley and M. L. Buchanan. 1950. Stimulation of gain of swine by cobalt and APF. J. An. Sci. 9:654.

Dukes, H. H. 1947. The Physiology of Domestic Animals. New York: Comstock Pub. Co.

DuToit, P. J., A. F. Malan and P. K. van der Merwe. 1939. The feeding of phosphate to cattle in their drinking water. Farming in S. Africa Nov.:429.

Eckles, C. H. and R. B. Becker. 1926. A mineral deficiency in the ration of cattle. Minn. Agr. Expt. Sta. Bul. 229.

Eckles, C. H. and T. W. Gullickson. 1927. The relation of phosphorus deficiency to the utilization of feed. Am. Soc. An. Prod. Proc. p. 16.

Eckles, C. H., T. W. Gullickson and L. S. Palmer. 1932. Phosphorus deficiency in rations of cattle. Minn. Agr. Expt. Sta. Tech. Bul. 91.

Edgar, Grahme. 1936. Fatal effect of heavy infestation with Cooperia curticei in goats. Aust. Vet. J. 12:58.

Forbes, E. B. and F. M. Beagle. 1918. The mineral metabolism of the milk cow. Ohio Agr. Expt. Sta. Bul. 295.

Forbes, E. B., W. W. Braman and M. Kriss. 1932. The heat production of cattle in a respiration calorimeter as related to the rate of ventilation and to the moisture content of the air. J. Nutr. 5:387.

Foster, A. O. and W. W. Cort. 1932. The relation of diet to susceptibility of dogs to Ancylostoma caninum. Am. J. Hyg. 16:241.

Foster, A. O. and W. W. Cort. 1931. The effect of diet on hookworm infestation in dogs. Sci. 73:681.

Foster, A. O. and W. W. Cort. 1935. Further studies on the resistance of dogs to hookworm infestation. Am. J. Hyg. 21:302.

Foster, A. O. 1953. Free-choice phenothiazine for cattle. Vet. Med. 48:208.

Gaalaas, R. F. 1945. Effect of atmospheric temperature on body temperature and respiration rate of Jersey cattle. J. Dairy Sci. 28:555.

Gaalaas, R. F. 1947. A study of heat tolerance in Jersey cows. J. Dairy Sci. 30:78.

Gall, L. S., S. E. Smith, D. E. Backer, C. N. Stark and J. K. Loosli. 1949a. Rumen bacteria in cobalt deficient sheep. Sci. 109:468.

Gall, L. S. 1949b. Effect of ration on rumen flora of cattle and sheep. J. An. Sci. 8:619.

Grinnells, C. D. 1950. Parasites and pasture. Res. Farm. 9:38.

Gubler, C. J., M. E. Lahey, M. S. Chase, G. E. Cartwright and M. M. Wintrobe. 1952. The metabolism of iron and copper deficient swine. J. Hematology 7:1053.

Habermann, R. T. and P. D. Harwood. 1940. Efficacy of recrystallized phenothiazine for the removal of nematodes from the gastro-intestinal tract of sheep. Vet. Med. 35:24.

Harwood, P. D., R. T. Habermann and A. C. Jerstad. 1939. Efficacy of commercial phenothiazine in the removal of roundworms from sheep. Vet. Med. 34:440.

Heitman, Jr., H. and E. H. Hughes. 1949. Effects of air temperature and relative humidity on the physiological well being of swine. J. An. Sci. 8:171.

Heitman, Jr., H., E. H. Hughes and C. F. Kelly. 1951. Effects of elevated ambient temperature on pregnant sows. J. An. Sci. 10:907.

Herlich, H. and D. A. Porter. 1954. Control of Internal parasites of cattle by free-choice administration of Phenothiozine.

Hodgson, C. W., R. F. Johnson, A. C. Wiese and C. W. Hickman. 1948. A comparison of steamed bonemeal and defluorinated superphosphate as phosphorus supplement for fattening steers. J. An. Sci. 7:273.

Huffman, C. F. 1933. Role of minerals in the dairy ration. Mich. Agr. Exp. Cir. Bul. 207:1.

Ittner, N. R. and C. F. Kelly. 1951. Cattle shades. J. An. Sci. 10:184.

Ittner, N. R., C. F. Kelly and H. R. Gulibert. 1951. Water consumption of Hereford and Brahman cattle and the effect of cooled drinking water in a hot climate. J. An. Sci. 10:742.

Jordan, W. H., E. B. Hart and A. J. Patten. 1906. A study of the metabolism and physiological effects of certain phosphorus compounds with milk cows. N. Y. Expt. Sta. Tech. Bul. 1.

Kelly, C. F. and N. R. Ittner. 1948. Artificial shades for livestock in hot climates. Ag. Eng. 29:239.

Kelly, C. F., H. Heitman, Jr. and Jack R. Morris. 1948. Effect of environment on heat loss from swine. Ag. Eng. 29:525.

Kendall, J. C. 1931. Perspiration as a factor in animal metabolism. N. Hamp. Agr. Expt. Sta. Ann. Rept. Bul. 256:5.

Kibler, H. H., S. Brody and D. M. Worstell. 1949. Environmental physiology. IV. Influence of temperature 50 - 105 degrees F. on heat production and cardiorespiratory activities in dairy cows. Mo. Agr. Exp. Sta. Res. Bul. 435:1.

Kibler, H. H., and S. Brody. 1950. Environmental physiology. Influence of temperature 50 - 105 degrees F., and 50 - 9 degrees F on heat production and cardiorespiratory activities of Brahmans, Jerseys, and Holsteins. M. Agr. Exp. Sta. Res. Bul. 450:1.

Kleiber, Max, H. Goss and H. E. Guilbert. 1936. Phosphorus metabolism and food utilization in beef heifers. J. Nutr. 12:121.

Kleiber, Max, W. M. Regan and S. W. Mead. 1945. Measuring food value for dairy cows. Hilgardia 16:11.

Know, J. H., J. W. Benner and W. E. Watkins. 1941. Seasonal calcium and phosphorus requirements of range cattle, as shown by blood analyses. New Mex. Agr. Expt. Sta. Bul. 282.

Lahey, M. E., C. J. Gubler, J. S. Chase, G. E. Cartwright and M. M. Wintrobe. 1951. Role of copper in erythropoiesis. Am. J. Physiol. 167:804.

Lantow, J. L. 1932. Minerals for range cattle. Proc. Am. Soc. An. Prod. p. 71.

Loosli, J. K., C. F. Huffman, W. E. Peterson and P. Phillips. 1950. Recommended nutrient allowances for dairy cattle. Nat. Res. Council Bul.

Levine, R. L. 1954. Phenothiazine; Limits in parasitism. Sowest. Vet. 7:243.

Marston, H. R. 1938. Studies on "Coast disease" of sheep in south Australia. Aust. Council for Sci. and Ind. Res. Bul. 113:1.

Martin, C. J. and I. Clunies Ross. 1934. A minimal computation of the amount of blood removed daily by Haemonchus contortus. J. Helm. 12:137.

Maynard, L. A. and J. K. Loosli. 1943. Mineral nutrition. Ann. Rev. of Biochem. 12:262.

Maynard, Leonard A. 1947. Animal Nutrition. McGraw-Hill Book Co., New York.

McCance, R. A. and E. A. Widdowson. 1944. Mineral metabolism. Ann. Rev. of Biochem. 13:315.

Miller, G. D., J. B. Frye, B. J. Burch, Jr., P. J. Henderson and L. L. Rusoff. 1951. Effect of sprinkling on the respiration rate, body temperature, grazing performance, and milk production of dairy cattle. J. An. Sci. 10:961.

Morrison, F. B. 1939. Feeds and Feeding. 20th Ed. Morrison Pub. Co., Ithaca, New York. p. 115.

Moxon, A. L., T. M. Paulsen, and L. E. Johnson. 1947. Blood calcium and phosphorus levels in range cattle. J. An. Sci. 6:489.

Nance, John A. 1952. Phosphorus requirements of range beef cattle. Doctor of Philosophy Thesis. Part I. Okla. A. and M. College.

Nelson, A. B., W. D. Gallup, O. B. Ross, and J. A. Nance. 1951. Reproduction of lactation performance of range cows fed various levels of phosphorus. Okla. Agr. Exp. Sta. Misc. Pub. MP-22.

Nelson, A. B., W. D. Gallup, O. B. Ross, and J. A. Nance. 1951. Do beef cattle need additional trace minerals in southeast Oklahoma? Okla. Agr. Exp. Sta. Misc. Pub. MP-22.

Nelson, A. B., J. A. Nance, W. D. Gallup, A. E. Darlow and W. D. Campbell. 1952. Effect of high levels of manganese intake on the performance of beef cows. Okla. Agr. Exp. Sta. Misc. Pub. MP-27.

Noland, P. R., J. P. Willman and F. B. Morrison. 1951. Vitamin and mineral supplements for growing and fattening pigs in drylot. J. An. Sci. 10:875.

Palmer, L. S., W. S. Cummingham and C. H. Eckles. 1930. Normal variation in the inorganic phosphorus of the blood of dairy cattle. J. Dairy Sci. 13:174.

Palmer, L. W., T. W. Gullickson, W. C. Boyd, C. P. Fitch and J. W. Nelson. 1941. The effect of rations deficient in phosphorus and protein on ovulation, estrous, and reproduction of dairy heifers. J. Dairy Sci. 24:199.

Peterson, E. H., R. J. Webb and W. G. Kammlade. 1943. Effectiveness of a 1-14 phenothiazine-salt mixture in controlling nematode infection in sheep. Am. J. Vet. Res. 5:228.

Pierce, E. A. 1954. The effects of ration containing antibiotics and trace mineral salt on the chemical composition and physical characteristics of prok carcasses. J. An. Sci. 13:338.

Plumlee, M. P., Robert Totusek and W. M. Beeson. 1953. The effect of adding trace minerals to rations of identical twin cattle. J. An. Sci. 12:928.

Pope, L. S., D. Stephens, P. E. Loggins and V. G. Heller. 1953. Protein and mineral supplements for wintering two-year-old steers on native grass. Okla. Agr. Exp. Sta. Misc. Pub. MP-31:121.

Porter, D. A., L. E. Swanson, and T. S. Drake. 1941. The duration of infectivity of nematode parasites of cattle of Florida pastures with observations on resistance of calves to natural reinfection with H. contortus. J. Parasitology, 27:22.

Porter, Dale A. 1942. Keeping Livestock Healthy. Yearbook of Agriculture. U. S. Gov't. Print. Off.

Porter, D. A., and G. E. Cauthen. 1946. Experimental infection of calves with the small stomach worm, O. ostertagi. J. Parasitology. 32:14.

Price, D. A., W. T. Hardy and I. B. Boughton. 1953. Phenothiazine salt mixture for control of Haemonchus contortus in range sheep. J. Am. Vet. Med. Asso. 123:132.

Ransom, B. B. 1906. The life history of the twisted wireworm (Haemonchus controtus) of sheep and other ruminants. U. S. Bur. An. Ind. Cir. 93:7.

Ransom, B. H. 1920. Intestinal lesions in calves due to Cooperis punctata. J. Parasitology 7:96.

Regan, W. M. and G. A. Richardson. 1938. Reactions of the dairy cow to changes in enviromental temperature. J. Dairy Sci. 21:73.

Regan, W. M. and S. W. Mead. 1939. The effect of changes in environmental temperature on water consumption of producing dairy cows. J. Dairy Sci. 22:472.

Reinerschmid, G. 1943. The amount of solar radiation and its absorption on the hairy coat of cattle under S. African and European conditions. J. South African Med. Assoc. 14:121.

Rhoad, A. O. 1936. The influence of environmental temperature on the respiratory rhythm of dairy cattle in the tropics. J. Agr. Sci. 26:36.

Rhoad, A. O. 1938. Some observations on the response of purebred Bos taurus and Bos indicus cattle and their crossbred types to certain conditions of the environment. Am. Soc. An. Prod. Proc. 284.

Rhoad, A. O. 1942. A scale of heat tolerance for cattle. J. An. Sci. 1:85.

Richard, R. M., R. F. Ghumard, A. L. Pope, P. H. Phillips, C. A. Herrick, G. Bohstedt. 1954. The effect of certain mineral supplements on lambs infected with the stomach worm Haemonchus contortus. J. An. Sci. 13:274.

Riddell, W. H., J. S. Hughes and J. G. Fitch. 1934. The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Kan. Agr. Expt. Sta. Tech. Bul. 36.

Russell, F. C. 1947. Minerals in Pasture. Deficiencies and excesses in relation to animal health. Penn. Exp. Sta. Bul. 489.

Seath, D. M. and G. D. Miller. 1946a. Effect of warm weather on grazing performance of milking cows. J. Dairy Sci. 29:199.

Seath, D. M. and G. D. Miller. 1946b. The relative importance of high humidity as a factor influencing respiration rate, body temperature, and pulse rate of dairy cows. J. Dairy Sci. 29:465.

Seath, D. M. and G. D. Miller. 1948a. Effect of water sprinkling with and without air movement on cooling dairy cows. J. Dairy Sci. 31:361.

Seath, D. M. and G. D. Miller. 1948b. A self-serving sprinkling device for cooling dairy cattle. J. An. Sci. 7:251.

Shorb, D. A., R. T. Habermann and L. C. Heemstra. 1941. Comparison of the efficacy of phenothiazine and CuSO4-nicotine sulfate mixture as anthelmintics for sheep. Vet. Med. 36:502.

Snell, E. L. 1936. Parasitic enteritis. The transference of the causative helminths from sheep to cattle. Vet. J. 93:353.

Spedding, C. R. W. 1952. Variation in the egg count of sheep feces within one day. J. Helm. 12:137.

Speer, V. C., D. V. Catron, P. G. Homeyer and C. C. Culbertson. 1952. Trace minerals for growing-fattening swine in drylot. J. An. Sci. 11:113.

Stoll, Norman R. 1936. Observations on cattle nematode infections, with a demonstration of their secondary transmission to grazing sheep. J. Parasitology 22:386.

Swanson, L. E., P. D. Harwood and J. W. Connelly. 1941a. Phenothiazine as an anthelmintic for the removal of intestinal worms from swine. Vet. Med. 26:56.

Swanson, L. E. and B. E. Carlisle. 1941b. Phenothiazine as an anthelmintic for cattle under field conditions. Vet. Med. 36:312.

Swanson, L. E. 1942. Longevity of eggs and larvae of internal parasites of cattle. Fla. Agr. Expt. Sta. Rept. p. 71.

Swanson, L. E. 1945. Longevity of eggs and larvae of internal parasites of cattle. Fla. Agr. Expt. Sta. Rept. p. 52.

Swanson, L. E., W. R. Dennis and W. M. Stone. 1954. Internal parasites of cattle, their control with phenothiazine and management. Fla. Cir. S-78.

Tash, L. G. and J. M. Jones. 1947. Phosphorus for range cattle. The Cattleman 33:25.

Taylor, E. L. 1934. The interaction of nutrition and parasitism with special reference to parasitic gastritis. Vet. Rec. 55:117.

Taylor, E. L. 1937. Parasitic enteritis. The transference of the causative helminths from sheep to cattle. Vet. J. 93:353.

Tetley, J. H. 1953. Inhibition of population of Haemonchus contortus in sheep fed on white clover. J. Helminthol., Nutr. Abs. Rev. 23:699.

Tetley, J. H. 1934. The nematodes of sheep in New Zealand. J. Helminthol. 12:183.

Theiler, A. H., H. H. Green and P. J. du Toit. 1928. Studies in mineral metabolism. III. Breeding of cattle on phosphorus deficient pasture. J. Agr. Sci. 18:369.

Thompson, H. J., D. M. Worstell and S. Brody. 1949. Environmental physiology. V. Influence of temperature of 50 - 105 degrees F. on water consumption in dairy cows. Mo. Agr. Expt. Sta. Res. Bul. 436.

Thorp, W. T. S., W. L. Henning and J. F. Shigley. 1944. The efficiency of the phenothiazine-salt mixture and drench for sheep. J. An. Sci. 3:242.

Thorp, W. T. S. and T. B. Keith. 1943. The use of phenothiazine for sheep and suggested method of administration. Vet. Med. 38:215.

Thorp, W. T. S., W. L. Henning and J. F. Shigley. 1945. Phenothiazine as an anthelmintic for breeding ewes. J. An. Sci. 4:133.

Tidwell, A. L. and J. L. Fletcher. 1951. The effect of summer environment on the body temperature and respiration rate of swine. J. An. Sci. 10:522.

Underwood, E. J. 1940. The significance of the "trace elements" in nutrition. Nutr. Abs. and Rev. 9:515.

Veglia, Frank. 1915. The anatomy and life history of Haemonchus contortus. Union S. Africa. Dept. Agr. Repts. Dir. Vet. Res. 3:347.

Vegors, H. H., O. E. Sell, D. M. Baird and T. B. Stewart. 1953. Internal parasitism of beef calves on three kinds of winter pastures. Proc. Assoc. Southern Agr. Workers, p. 79.

Watkins, W. E. and J. H. Knox. 1948. Inorganic blood phosphorus levels necessary for satisfactory production of range cattle in the Southwest. J. An. Sci. 7:263.

Weir, W. G., T. L. Bahler, A. L. Pope, P. H. Phillips, C. A. Herrick and G. Bohstedt. 1948. The effect of hemopioetic dietary factors on the resistance of lambs to parasitism with the stomach worm, Haemonchus contortus. J. An. Sci. 7:466.

Wells, H. S. 1931. An observation which suggests an explanation of the anemia in hookworm disease. Sci. 73:16.

Whitehurst, V. E. and L. E. Swanson. 1942. Phenothiazine as an anthelmintic for sheep. J. An. Sci. 1:256.

Willman, J. P. and D. W. Baker. 1943. Phenothiazine for the control of stomach and nodular worms in sheep. J. An. Sci. 2:372.

Willman, J. P. and P. R. Noland. 1949. Improved pig rations. Farm Res. 15.

INTRODUCTION

Simultaneous experiments were previously conducted at Stillwater in north central Oklahoma, and at Wilburton in southeastern Oklahoma, to determine the phosphorus requirements of range beef cattle. In southeastern Oklahoma most of the soils are known to be deficient in phosphorus, while the soils in the north central area are on a border-line phosphorus deficiency.

Three levels of phosphorus were fed in each of the two experiments, a low, medium, and high level. Although the cattle at Wilburton showed an improvement in reproductive performance when fed the higher levels of supplemental phosphorus, they did not perform as satisfactorily as the cattle located at the Stillwater station. At the Wilburton station, the percentage calf crops, weaning weights of the calves, and yearly gains of the cows were notably smaller. The death losses of calves at calving time were also extremely high.

The importance of feeding trace minerals to weanling and yearling Hereford heifers was also studied at the Wilburton Station. It was concluded from the data obtained that it was not beneficial to feed the trace minerals.

It was observed by analysis that the forage grown in the Wilburton area contained a much higher manganese content than 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. A high level of manganese in the ration of beef cattle was reported by workers in other areas to be detrimental, causing various reproductive difficulties and decreased gains.

Studies were initiated at the Stillwater station to determine the effect of high levels of manganese on reproduction, blood constituents, and weight gains of range beef cows. The third year's results of this experiment are reported in Part II of this thesis.

REVIEW OF LITERATURE

MANGANESE

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 found that female rats on a manganese deficient ration had normal estrus cycles and produced an average number of normal young. However, 97 per cent of the females failed to suckle their young. Manganese deficient young on foster mothers were undersize and inferior in appearance. The male rats had testicular degeneration. The rats fed a diet deficient in manganese grew normally, but their haircoats became rough after approximately eight months. McClure (1949) noted testicular atrophy and sterility in adult rats on a low manganese diet. Amdur et al. (1945) noted inferior bone development in rats on low manganese diets as compared to rats fed adequate amounts of manganese. Skinner and McHargue (1946) found evidence in support of the role of manganese in synthesis of hemoglobin in the rat.

Manganese is also known to prevent perosis in poultry and to be necessary for normal skeletal development and growth in several species including swine, according to Maynard (1947). Johnson (1940) fed a semi-purified ration containing 0.3 ppm. manganese to pigs and obtained satisfactory growth response. Reproduction was poor, but was not improved by adding manganese. Grummer et al. (1948) reported that pigs made greater gains on less feed when a basal ration was supplemented with 40 ppm. of manganese. Larger amounts did not increase gains accordingly.

Most workers agree that the level of calcium and phosphorus in the diet is important in determining the manganese requirement for an animal (Lyons, 1938; McCollum, 1947; Morrison, 1948).

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. 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. Johnson (1944) reported satisfactory gains with pigs fed a ration containing 7 to 10 ppm. of manganese.

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 five months, while ewes receiving 100 ppm. of manganese gained an average of 42 pounds.

Apparently a small amount of manganese is an essential dietary constituent for livestock. However, large amounts may be harmful to animals. Experiments were conducted by Grummer *et al.* (1940) to determine the effect of a high level of manganese on the growth of pigs. Lot 1 received only a basal ration; Lot 2 was fed the basal plus 500 ppm. of manganese. The pigs on the basal ration gained 1.21 pounds per day 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.

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 550 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 resulted in decreased yearly gains of the cows. There were no differences in the weaning weights of the four lots of calves. The second year the cows receiving 500 ppm. manganese made considerably smaller gains during the summer grazing season than cows in lot 1, lot 2 and lot 4. Calves from cows receiving 250 ppm. manganese had a lower average weaning weight than the other three lots.

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. manganese sulfate was added to a basal ration 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 affected by increasing the manganese intake. It was also observed that when 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.

A condition in rats called "Manganese rickets", was produced by Blumberg and coworkers, (1938). The condition was produced by adding 2.9 per cent manganese carbonate to a high calcium and low phosphorus diet and by adding 2.9 per cent manganese carbonate to a stock ration of optimal calcium and phosphorus content.

Nance (1952) found that the addition of 1,000 ppm. of manganese to a basal ration of prairie hay, corn gluten meal, ground wheat, ground oats, alfalfa meal, Delsterol, and salt, fed to female rabbits, resulted in an apparent impairment of the reproduction and lactation of the does. When 2,000 ppm. of manganese was added to the basal ration, growth was retarded in each trial. The retardation of growth was partially counteracted by bone meal supplementation.

Skinner and Peterson (1931) fed various levels of manganese to rats. Female rats on a manganese intake of 50 mg. per rat daily were unable to properly nourish their young after several litters. 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 female on the stock ration alone. Even when 2,000 ppm. of manganese sulfate was added to the ration of weaning 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 9,980 ppm. were added to a stock ration containing 0.72 per cent phosphorus and 0.63 per cent calcium. The only retardation of growth was noted at the 9,980 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 amounts of absorbable manganese".

Perla and Sandberg (1939) stated that administration of vitamin B_1 minimized the effect of a toxic dose of manganese and that administration of manganese minimized the effect of a toxic dose of vitamin B_1. They also showed 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. Nance (1952) reported that brewer's yeast completely counteracted the growth retardation caused by high levels of manganese in the ration of rabbits.

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

Blakemore and coworkers (1937) believed that grasses particularly high in manganese would possibly lower the blood magnesium, thus contributing to lactation tetany of cows and sheep. Monier-Williams (1949) reported that grass containing 540 to 732 ppm. of manganese was thought to be concerned with lactation tetany. Underwood (1940) stated that in lactation tetany areas the forage contained an average of 734 ppm. manganese. The healthy areas contained only 59 ppm. Russell (1944) reported that while manganese excesses seem to be the cause of forage anemia and predispose the animal to infectious anemia no actual proof can be offered.

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, according to Bolin (1934). He found the manganese content ranged from 70.1 ppm. in Kentucky bluegrass to 207.5 ppm. in orchard grass on a dry basis. Alfalfa contained an average of 46.6 ppm. of manganese. Skinner and Peterson (1928) stated that alfalfa hay contained 72 ppm. and Kentucky bluegrass 59 ppm. of manganese. The amount of manganese which a plant can obtain from the soil is apparently due to several factors. The lack of drainage tends to increase manganese content of oats as much as 6 times its level on drained soil, according to Gooden and Grimmett (1928). The manganese content of plants is decreased when the soils are limed.

EXPERIMENTAL

The following experiment was started at the Lake Carl Blackwell Range Area near Stillwater in 1950. The third year's work is reported here. Originally, 64 grade Hereford cows were divided into four equal lots of 16 cows each. Two cows were removed from the experiment at the end of the first year, one from Lot 3 because of a prolapsed uterus and one from Lot 4 because of enlarged ovaries and a tumor on the uterus. Two more cows were removed at the end of the second year, one from Lot 2 because of a spoiled udder and one from Lot 3 because of a mumified fetus.

During the winter season the cows in all Lots were confined to small traps and fed prairie hay, free-choice, 1.4 pounds of corn gluten meal per head daily (fed on alternate days), and loose salt, free-choice. The cows of Lot 1 served as controls. Lot 2 cows were fed a commercial grade of manganese sulfate[1] in amounts to supply manganese at a level of approximately 250 ppm. of the ration. The actual intake of supplemental manganese was 1.68 grams per head daily. Lot 3 received the same basal ration plus enough manganese sulfate to provide a daily intake of approximately 500 ppm. of manganese (3.97 grams of supplemental manganese per cow daily). The cows of Lot 4 received the same basal ration plus enough manganese sulfate to supply 500 ppm. manganese, and 400 mg. of supplemental ferric sulfate and

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

40 mg. of copper sulfate per head daily. Since the hay contained 68 ppm. of manganese, the difference between 68 ppm. and 250 or 500 ppm. represents the proportion of added manganese. The minerals were mixed with the corn gluten meal and fed in a trough.

The cows in all lots grazed native grass pastures during the summer months, with free access to salt at all times. The mineral supplements were fed to all lots during the pasture season by mixing with corn, which was fed at the rate of 1 pound per head daily on alternate days. The cows of Lot 1 received no supplemental minerals and none of the lots received any supplemental phosphorus.

Bulls were placed with the cows on May 1 and removed in late August, and were rotated among the lots to minimize sire differences and breeding efficiency. Calves were weaned October 12 at approximately seven to eight months of age.

One-half of the cows in each lot were bled at 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 the blood samples were taken. Randomly picked samples of three climax grasses, big bluestem, Indian, and little bluestem were taken during June and July and analyzed for dry matter, ash, protein, ether extract, fiber, nitrogen-free extract, calcium, and phosphorus. The chemical composition of the feeds and grasses is presented in Table I.

Table I. Chemical Composition of Grasses and Feeds

	Percent composition of dry matter						
	Ash	Prot.	Ether Extract	Fiber	NFE.	Ca.	Phos.
Prairie Hay	7.02	4.64	1.95	31.28	55.11	0.38	0.055
Corn Gluten Meal	3.18	47.39	1.69	3.24	44.50	0.40	0.48
<u>Grasses</u>[1]							
June 1953	6.82	7.73	2.76	30.80	51.89	0.32	0.096
July 1953	7.27	6.89	3.39	32.51	49.93	0.32	0.103

[1]Each grass sample consisted of the three climax grasses, Big Bluestem, Indian, and Little Bluestem.

RESULTS AND DISCUSSION

Cow Data

Table II shows the weight data of the cows for both the winter and summer seasons. The low initial weight of the cows receiving a high level of manganese supplement alone (Lot 3) should be noted. This low weight was due to the comparatively low gains of these cows during the previous summer. Although the cows of Lot 3 gained slightly more than the cows of the other three lots during the third year, their total average weight at the end of the year was 126, 73, and 118 pounds lower than the average weight of Lot 1, 2, and 4, respectively. This was possibly due to the intake of a high level of manganese. Morrison (1947) stated that although manganese is considered an essential element in the diet, an excess tends to cause a retardation of growth, decreased appetite, and decreased yearly gain.

Iron and copper were added to the ration of Lot 4 to determine their effect in a high manganese ration, since Russel (1947) in Scandanavia reported an anemia among horses grazing forages high in manganese. No anemia has been observed in this experiment. However, since the weight of the cows receiving the highest level of manganese (Lot 3) was considerably below that of the control cows (Lot 1) or those receiving iron and copper (Lot 4) after three years, it is possible that the supplemental iron and copper exert a beneficial influence in a high manganese ration.

Table II. Summary of Cow Weight Data.

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 (11-4-52)	16	15[1]	14	15
Average weight of cows (lbs.)				
Initial 11-4-52	1118	1078	967	1121
Before calving 1-31-53	1143	1108	996	1098
End of winter feeding 4-23-53	844	860	772	874
Final 11-10-53	1115	1062	989	1107
Weight gain or loss (lbs.)				
Winter gain to calving	25	30	29	--23
Total winter loss	--274	--218	--195	--247
Summer gain	271	202	217	233
Yearly gain or loss	--3	--16	22	--14
Birth weight of calves[2]	82	80	77	80
Number of calves weaned	16	13[1]	13[3]	14[3]
Weaning weight of calves[4] 10-12-53	475	473	460	466

[1]Two cows in Lot 2 died during or shortly after calving, one because of a prolapsed uterus and one from septicemia.

[2]Corrected for sex by adding 5 lbs. to the actual birth weight of each heifer.

[3]One calf born dead.

[4]Actual weaning weights were corrected: (1) for age by adjusting all calves to a standard age of 210 days, and (2) for sex by adding 25 lbs. to the age corrected weight of each heifer.

Although differences have not been marked, the mortality rate of cows has been higher in the lots receiving supplemental manganese than in the control lot. Calf losses have also been higher in the manganese lots. It cannot be definitely concluded whether this is a toxic effect of manganese until more conclusive data are obtained.

Calf Data

A summary of the calf data is given in Table II. There were small differences in birth weight and per cent calf crop among the four Lots, but these differences were not considered large enough to be important and could not be associated with the differences in treatment. At weaning time Lot 1 calves averaged 2 pounds heavier than Lot 2, 15 pounds heavier than Lot 3, and 9 pounds heavier than Lot 4. These differences were not significant (P<5 per cent). Although Blucker (1953) found significant differences in calf weaning weights the second year, Nelson (1952) failed to find any appreciable differences the first year. Considering the three years work thus completed, high levels of manganese have had no marked and consistent effect on calf weaning weight.

Blood Data

A summary of the blood analysis may be observed in Table III. The plasma phosphorus values were very low during the winter with average values as low as 2.35, 1.78, 1.03, and 1.58 mg. per 100 ml. of plasma, for Lots 1, 2, 3, and 4, respectively. These low values, which are considered to represent a critical state of phosphorus nutrition occurred during January, March, and April. The average for all lots was less than 3 mg. per 100 ml. plasma throughout the winter period. However, no marked clinical symptoms of a phosphorus deficiency other than low blood phosphorus values were observed. Maynard (1947), and Huffman (1933) reported that plasma phosphorus levels below

4 mg. per cent were indicative of a pending aphosphorosis. However, Knox et al. (1947) reported that range beef cattle remained healthy and reproduced normally when their plasma phosphorus levels dropped as low as 2.00 mg. per 100 ml. of plasma.

The plasma phosphorus level of Lot 3 remained consistently lower than the values for the other Lots during the winter period. This is in agreement with work the previous year by Blucker (1953). However, the first year (Nelson, 1952) plasma phosphorus levels of Lot 3 remained consistantly higher than the values for the other lots during the winter period.

At the beginning of the grazing season the plasma phosphorus values began to rise and reached levels of about 5 mg. during July. During the summer months the plasma phosphorus levels fluctuated considerably, but could not be correlated with the treatments.

Differences in hemoglobin, hematocrit, plasma protein, and number of red blood cells were small among the lots.

Table III. Blood Constituents of Cows.

Lot	11-4-52	1-8-53	1-31	3-20	4-23	7-2	7-14	8-4	9-8
	Phosphorus (Mg. per 100 ml. plasma)								
I	4.28	2.54	2.35	2.50	2.09	5.35	3.82	2.97	4.51
II	5.39	3.13	2.43	1.98	1.78	3.00	5.16	4.90	4.20
III	2.40	1.66	1.59	1.03	1.92	5.74	4.98	5.92	3.37
IV	4.54	2.58	2.04	1.58	1.82	5.92	4.48	5.47	5.40
	Hemoglobin (Gm. per 100 ml.)								
I	12.9	11.3	11.3	10.9	10.7	12.1	12.8	11.8	12.2
II	12.2	11.9	11.5	10.5	10.3	11.3	11.9	11.0	12.4
III	11.7	10.5	9.9	9.3	9.8	11.3	11.0	11.0	11.5
IV	12.0	10.9	11.6	11.6	10.9	11.0	12.2	10.3	11.7
	Hematocrit (Volume per cent)								
I	38	34	33	34	31	35	--	--	38
II	37	35	33	33	29	35	--	--	37
III	34	31	30	30	29	32	--	--	34
IV	35	32	33	36	32	32	--	--	34
	Plasma Protein (Gm. per 100 ml.)								
I	7.20	7.06	7.19	6.73	6.48	7.37	7.12	6.76	7.19
II	6.98	7.21	6.80	6.31	6.04	6.64	6.40	6.34	6.79
III	6.43	6.60	6.26	5.47	5.77	6.52	6.10	6.33	6.80
IV	6.79	6.56	7.06	6.89	6.38	6.56	6.87	5.90	6.87
	Red Blood Cells (Millions per cu. mm.)								
I	8.90	8.62	8.27	7.82	8.35	8.53	--	--	8.09
II	8.18	7.93	7.99	7.88	7.66	7.81	--	--	7.96
III	8.77	8.08	8.43	8.31	8.25	7.95	--	--	8.23
IV	8.55	8.11	8.37	7.99	8.05	7.83	--	--	8.20

SUMMARY

An 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. During the winter season the cows in all lots were confined to small traps. The basal winter ration consisted of prairie hay free-choice, and 1.4 pounds of corn gluten meal per head daily, fed on alternate days. The cows in all lots grazed native grass pastures during the summer months. Loose salt was provided at all times. 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. Lot 3 was fed the same basal ration with the manganese content raised to 500 ppm. Lot 4 also received the basal ration with a total of 500 ppm. of manganese and in addition 400 mg. of iron and 40 mg. of copper per cow daily.

The results of the third years work of this experiment may be summarized as follows.

1. Differences in weight changes of the cows were small during the year. However, the average weight of the cows that received 500 ppm. manganese was considerably lower throughout the year than that of the control cows, those that received 250 ppm. manganese, and those that received iron and copper in addition to 500 ppm. manganese.

2. The plasma phosphorus values of all lots were very low during the winter months, however, no marked clinical symptoms of a phosphorus deficiency other than low blood values were observed. During the summer months the plasma phosphorus levels fluctuated considerably, but could not be correlated with the treatment.

3. Differences in hemoglobin, hematocrit, plasma protein, and number of red blood cells were small among the Lots.

4. Differences in birth weight, per cent calf crop and weaning weight of the calves were not significant.

LITERATURE CITED

Amdur, M. O., L. C. Norris and G. F. Heuser. 1945. The need for manganese in bone development by the rat. Proc. Soc. Expt. Biol. and Med. 59:254.

Becker, J. E. and E. V. McCollum. 1938. Toxicity of MnCl2 · 4H20 when fed to rats. Proc. Soc. Expt. Biol. Med. 38:740.

Bentley, O. G., G. V. Quicke, J. Kastalic and Paul Phillips. 1951. Certain trace elements in the feeds, organs, and tissues of a selected group of repeat breeding cows in northern Wisconsin. J. Dairy Sci. 34:363.

Bentley, O. G. and P. H. Phillips. 1951. The effect of low manganese rations upon dairy cattle. J. Dairy Sci. 34:396.

Blakemore, F., J. A. Nicholson and J. Stewart. 1937. Some effects of a high manganese content in the diet of animals with special reference to lactation tetany. Vet. Rec. 49:415.

Blucker, J. D. 1953. Mineral and management studies with range beef cattle. Master of Science Thesis, Okla. A. and M. College.

Blumberg, H., D. H. Shelling and D. A. Jackson. 1938. The production of manganese rickets in rats. J. Nutr. 16:317.

Bolin, D. W. 1934. The manganese content of grasses and alfalfa from grazed plots. J. Agr. Res. 48:657.

Caskey, C. D., W. D. Gallup and L. C. Norris. 1939. The need for manganese in the bone development of the chick. J. Nutr. 17:407.

Chornock, Charlotte, N. B. Guerrant and R. Adams Dutcher. 1942. Effect of manganese on calcification in the growing rat. J. Nutr. 23:445.

Cox, G. J., M. L. Dodds, H. B. Wigman and F. J. Murphy. 1931. The effects of high doses of aluminum and iron on phosphorus metabolism. J. Biol. Chem. XII:92.

Daniels, A. L. and G. J. Elvehjem. 1935. The effect of feeding high amounts of manganese as to congenital debility. J. Nutr. 9:191.

Gooden, W. and R. E. R. Grimmett. 1928. Factors affecting the iron and manganese content of plants with special reference to herbage causing "Pining" and "Bushsickness." J. Agri. Sci. 18:363.

Grummer, R. H., C. K. Whitehair, G. Bohstedt and P. H. Phillips. 1948. Vitamin A, vitamin C and niacin levels in the blood of swine. J. An. Sci. 7:222.

Grummer, R. H., O. G. Bentley, P. H. Phillips and G. Bohstedt. 1950 The rose of manganese in growth, reproduction and lactation of swine. J. An. Sci. 9:170.

Johnson, S. R. 1940. Manganese requirements for sheep and swine. Ark. Agri. Exp. Sta. Bul. 386:59.

Johnson, S. R. 1944. Studies with swine on low manganese rations of natural food stuffs. J. An. Sci. 2:14.

Keith, T. B., R. C. Miller, W. Thorp and M. A. McCarty. 1942. Nutritional deficiencies of a concentrate mixture composed of corn, tankage, soybean oilmeal and alfalfa meal for growing pigs. J. An. Sci. 1:120.

Lardy, Henry, Paul Boyer, James Shaw and Paul Phillips. 1942. Cattle need manganese to prevent breeding trouble. Wis. Agr. Exp. Sta. Bul. 456:53

Lyons, M., W. W. Insko, Jr., J. H. Martin and R. L. Phillips. 1938. Effects of intraperetioneal injections of manganese, zinc, aluminum and iron salts on the occurrence of slipped tendon in chicks. Poult. Sci. 17:12.

Maynard, Leonard A. 1947. Animal Nutrition. McGraw-Hill Book Co., New York.

McClure, F. J. 1949. Mineral Metabolism. Ann. Rev. Biochem. 18: 344.

McCollum, E. V. and H. G. Day. 1947. The Newer Knowledge of Nutrition. MacMillan Co., New York.

Miller, R. C., T. B. Keith, M. A. McCarty and W. Thorp. 1940. Manganese as a possible factor influencing the occurrence of lameness in pigs. Proc. Soc. Biol. and Med. 45:50.

Monier-Williams, G. W. 1949. Trace Elements in Food. New York: John Wiley and Sons, Inc.

Morrison, F. B. 1948. Feeds and Feeding. Morrison Pub. Co., New York.

Nance, J. A. 1952. Effects of high levels of manganese supplementation on reproduction and lactation of beef cattle and rabbits, and on the fecal excretion of calcium and phosphorus by steers. Doctor of Philosophy Thesis, Part II. Oklahoma A. & M. College.

Nelson, A. B., J. A. Nance, W. D. Gallup, A. E. Darlow and W. D. Campbell. 1952. Effect of high levels of manganese intake on the performance of beef cows. Okla. Agr. Exp. Sta. Misc. Pub. MP-27:63.

Nelson, V. E., J. M. Evvard and W. E. Sewall. 1929. The effect of manganese on the growth of rats. Proc. Iowa Acad. Sci. 36:267.

Norris, L. C., W. D. Gallup and C. D. Caskey. 1938. The role of manganese in bone development. J. Nutr. 15:14.

von Oettingen, W. F. 1935. Manganese: Its distribution, pharmacology and health hazards. Physiol. Rev. 15:175.

Orent, E. R. and E. V. McCollum. 1932. The estrual cycle in rats on a manganese free diet. J. Biol. Chem. 98:101.

Perla, David. 1939. The prevention of toxic manifestations of an excess of vitamin B_1 by supplements of manganese to the diet. Sci. 89:132.

Ray, T. W., and L. J. Deysach. 1942. Storage of manganese by thyroid. Effect on oxygen consumption of the Guinea pig. Proc. Soc. Exp. Biol. and Med. 51:228.

Reid, J. T., K. O. Pfan, R. L. Salsbury, D. B. Bender and B. M. Ward. 1947. The effect of manganese and other trace elements on the metabolism of calcium and phosphorus during early lactation. J. Nutr. 34:661.

Reineke, E. P. and C. W. Turner. 1945. The effect of manganese compounds and certain other factors in the formation of thyroxine in iodinated casein. J. Biol. Chem. 161:613.

Russell, F. C. 1944. Minerals in pasture: deficiencies and excesses in relations to animal health. Tech. Comm. No. 15. Imperial Bureau of Animal Nutrition.

Skinner, J. T. and W. H. Peterson. 1928. The iron and manganese content of feeding stuffs. J. Biol. Chem. 79:678.

Skinner, J. T. and W. H. Peterson. 1931. The manganese metabolism of the rat. J. Biol. Chem. 90:65.

Skinner, J. T. 1931. The effect of a high intake of manganese on the growth of rats. J. Nutr. 5:451.

Skinner, J. T. and J. S. McHargue. 1946. Supplementary effect of arsenic and manganese on copper in synthesis of hemoglobin. Am. J. Physi. 145:500.

Smith, S. E., Mary Medicot, and G. H. Ellis. 1944. Manganese deficiency in the rabbit. Arch. Biochem. 4:281.

Underwood, E. J. 1940. The significance of the "Trace Elements" in nutrition. Nutr. Abs. and Rev. 9:515.

Waddell, J., H. Steenbock, E. B. Hart and R. L. Patton. 1930.
Growth and reproduction of milk diets. J. Nutr. 4:53.

APPENDIX

Table I. Analysis of Variance of Calf Gains for Part I.

Treatment	Degrees of Freedom	Sum of Squares	Mean Square
Total	544	86093	1594
Phenothiazine	1	1368	1368
Shade	1	325	325
Minerals	2	1650	825
Error	50	82750	1655

Table II. Analysis of Variance of Calf Gains for Part II.

Treatment	Degrees of Freedom	Sum of Squares	Mean Square
Total	55	93594	1701
Lots	3	1760	586
Error	52	91834	1766

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