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

By

JACK WESLEY MCASKILL

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Thesis Approved:

Robert Totusek
Thesis Adviser

Glen Bratcher
Head of Department

Robert MacVicar
Dean of the Graduate School

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INTRODUCTION

There have been reports of sub-normal performance of beef cattle in southeastern Oklahoma for a number of years previous to 1950. Cows of this area often had an unthrifty appearance, especially during the winter, and the percentage calf crop and the weaning weight of calves were low. A deficiency of phosphorus was thought to be one of the causes of poor beef cattle performance in this area.

Experiments were set up at Wilburton and Stillwater in 1947 to determine phosphorus requirements of range beef cattle in the two areas. High, medium, and low levels of phosphorus supplementation were used in each of these experiments. The cattle at Wilburton showed an improvement in reproductive performance when fed the high levels of supplemental phosphorus, but their performance was still unsatisfactory. compared to the cattle at the Stillwater station. The yearly gains of the cows, percentage calf crops, and weaning weights of the calves were notably smaller at the Wilburton station than at Stillwater. Death losses of calves at calving time were also high.

Studies have also been conducted at Wilburton to determine the value of feeding trace minerals. It was concluded from data obtained, that feeding a trace mineral mixture to weanling and yearling Herford heifers was not beneficial. More recent work at Wilburton has shown that continuous feeding of trace minerals to cows has no apparent influence on the weight and appearance of either the cows or their calves.

An analysis of the range grass and weeds showed that the forage grown in the Wilburton area contained a much higher manganese content than forage grown near Stillwater. Hay grown near Wilburton contained from 150 to 270 ppm. of manganese, whereas some weeds contained as much as 700 to 900 ppm. Hay grown near Stillwater contained 25 to 75 ppm. of manganese. It has been shown by some workers that a high level of manganese in the ration of beef cattle is detrimental, causing reproductive difficulties and decreased gain.

An experiment was set up at the Stillwater station in 1950 to study the effects of high levels of manganese on reproduction, weight gains, and certain blood constituents of range beef cows. Data reported in this thesis summarize the fourth and final year's work on this experiment. Data on liver and bone of cows that were slaughtered are also included.

REVIEW OF LITERATURE

MANGANESE

Manganese has been shown by many workers to be an essential constituent of the animal's diet. Orent and McCollum (1931) and Shils and McCollum (1943) found that rats on a manganese deficient diet failed to grow normally. The females gave birth to inferior young and in 97 per cent of the cases failed to suckle their young. Males developed testicular degeneration and sterility. Abnormal bone formation in rats on manganese deficient rations was noted by Amdur *et al*. (1945), and in rabbits by Smith *et al*. (1944). Perosis, an abnormal bone condition in poultry, has been shown to result from the lack of manganese by Wilgus *et al*. (1936), Wiese *et al*. (1937), Gallup and Norris (1938), and others. Miller *et al*. (1940) and Keith *et al*. (1942) found that manganese was effective in preventing lameness in pigs, while Johnson (1940) showed that a low level of manganese (10 ppm.) in a synthetic diet adversely affected weight gained and milk production of ewes, as compared to a ration containing 100 ppm. It was reported by Lardy *et al*. (1942) that bull calves maintained on a ration containing 28 ppm. manganese produced poor quality semen, and Bentley and Phillips (1951) showed that heifers on a ration with less than 10 ppm. manganese were slow to exhibit estrus and required more services per conception than heifers on higher levels of manganese (20 ppm.) Weak pasterns were noted on calves from the low manganese cows.

Although manganese in small amounts is apparently an essential constituent in the diet of livestock, it is thought that large amounts may be detrimental. Nelson et al. (1929) observed a stimulation of growth in rats when 100 ppm. of manganese sulfate was added to a basal diet of casein, dextrin, and salt; however, growth was retarded with the addition of 600 ppm. Work by Becker and McCollum (1938) showed that rations containing from 0.005 to 0.05 per cent manganese chloride permitted normal function in both male and female rats. No adverse effects were noted at any level up to 3.6 per cent; at that level growth was depressed, but reproduction was satisfactory at all levels. Chornock et al. (1942) found that with increasing levels of manganese intake there was an increase in calcium and phosphorus excretion resulting in a depletion of the body stores of these elements. The growth of rats fed a rachitogenic diet was retarded in proportion to the manganese content of the ration. These workers stated that manganese is stored, primarily, in the liver.

Blumberg et al. (1938) produced a condition called "Manganese rickets" in rats by adding 2.5 per cent manganese carbonate to a high calcium, low phosphorus ration, and by adding 2.9 per cent manganese carbonate to a stock ration containing adequate levels of calcium and phosphorus.

Skinner et al. (1931) observed the effects of various levels of manganese on rats. Mother rats on a manganese intake of 5 mg. per rat per day were unable, after rearing several litters, to properly nourish their young. Later, Skinner (1931) showed that female rats fed 10 mg. manganese per rat per day, in addition to a stock ration, were as successful in rearing their young as females fed the stock ration alone.

He also showed that growth was not retarded when weanling rats were fed a ration containing as much as 2,000 ppm. manganese sulfate for a twelve-week period.

In an experiment designed to determine the effect of high manganese intake on growth and reproduction of rabbits, Nance (1952) found that the addition of 1,000 ppm. manganese to a basal ration of prairie hay, corn gluten meal, ground wheat, ground oats, alfalfa meal, Delsterol, and salt resulted in an apparent impairment of reproduction and lactation of the does. In growth studies, the addition of 2,000 ppm. manganese retarded growth in every trial. The addition of bone meal partially counteracted this retardation of growth. These results, however, require confirmation.

Work with high levels of manganese for poultry has been contradictory. Gallup and Norris (1939) maintained chickens for 20 weeks on a ration containing 1,000 ppm. of manganese. They observed no toxic effects. Likewise, Insko et al. (1938) found that levels as high as 640 ppm. of manganese were not toxic to poultry. On the other hand, Van der Hoorn et al. (1938) reported some retardation of growth with levels of manganese above 300 ppm. Levels above 600 ppm. adversely affected normal barring and growth of feathers. Rations containing approximately 4800 ppm. manganese were found by Heller and Penquite (1937) to be extremely toxic to growing chicks. Slinger et al. (1951), in a trial designed to determine the effects of manganese and salt on bone abnormalities in turkey poults, found that at a manganese level of approximately 71 ppm. growth was retarded and bone ash was lowered. von Oettingen (1935), (quoted from Harnack), found that oral administration of manganese sulfate in large doses to dogs caused vomiting, gastritis, and paralysis. McCollum and Day (1947) stated that toxic effects of manganese are observed in animals only when the dose is so large that it causes gastric disturbances. These effects included degenerative changes in the central nervous system, the liver, and other organs.

Perla and Sandberg (1939) reported a metabolic interrelationship between manganese and vitamin B_1. They found that the addition of 2 mg. of manganese to a stock ration caused a disturbance in the lactation of female rats, and that this condition was alleviated by feeding thiamine. It was also shown that manganese minimized the effect of a toxic dose of vitamin B_1. In another trial, Perla _et al_. (1939) found that rats which received rations containing additional vitamin B_1 were able to consume larger amounts of manganese without adverse effects. Nance (1952) reported that the growth retarding effect of 2000 ppm. manganese in a ration for rabbits was counteracted by the addition of brewers yeast.

An experiment was conducted by Grummer _et al_. (1950) to determine the possible harmful effects of feeding high levels of manganese to pigs. The pigs on a ration containing no added manganese gained 1.2 pounds per day as compared to 0.97 pounds per day for the pigs receiving an additional 500 ppm. of manganese. Growth and appetite were affected by this level of manganese and these pigs exhibited a stiffness and a stilted gait during the latter part of the trial.

Reid _et al_. (1947) studied the effect of manganese and other trace elements upon calcium and phosphorus metabolism of dairy cows during lactation. Supplementation with manganese sulfate in addition to calcium carbonate resulted in a negative calcium balance in every case.

It was thought that the depression of calcium metabolism was due to the manganese sulfate. No appreciable effect on the phosphorus metabolism was noted.

An experiment was set up by Nelson et al. (1952) to determine the effects of high levels of manganese on beef cattle. Four lots of 16 cows each were used. Lot 1 served as control; Lot 2 was supplemented with enough manganese sulfate to supply a total of 250 ppm. of manganese; Lot 3 received a total of 500 ppm. of manganese; and Lot 4 received a total of 500 ppm. of manganese plus iron and copper. The first year, the feeding of high levels of manganese sulfate resulted in decreased yearly gains of the cows. The weaning weights of the calves were not affected. The second year, Blucker (1953) found that the cows receiving 500 ppm. manganese (Lot 3) had lower plasma phosphorus levels and made considerably smaller gains during the summer grazing season than the cows in Lots 1, 2, and 4. At weaning, calves from cows receiving 250 ppm. manganese (Lot 2) were lighter in weight than calves from cows of the other three lots. Swader (1955) reported that during the third year of this trial the differences in weight change of the cows, the plasma phosphorus levels, and the weaning weights of calves were very small; however, the cows in Lot 3 had a lower average weight throughout the year than the cows of the other lots.

Nance (1952) used 6 Hereford steers in a digestion trial to determine the effect of a high dietary level of manganese on the fecal excretion of calcium and phosphorus. The steers were divided into pairs and each pair was fed one of the following rations: (1) basal, (2) basal plus 12 gm. manganese sulfate (1000 ppm.), (3) basal plus 24 gm. manganese sulfate (2000 ppm.). It was found that steers which received added manganese voided in the feces a larger proportion of the dietary calcium and phosphorus than the steers on the basal ration. It was felt that this increased excretion of calcium and phosphorus was the result of the formation of an insoluble manganese phosphate complex in the gastro-intestinal tract. The results, however, were not conclusive. The inorganic phosphorus content of the blood plasma was apparently not affected by the high levels of manganese.

Ray and Deysach (1942) reported that with high levels of manganese there was an increased storage of manganese in the thyroid of guinea pigs. As the manganese storage of the thyroid increased, oxygen consumption decreased.

Hartman et al. (1955) fed manganese at different levels to lambs to test its effect on hemoglobin formation. In every case the lambs on the high levels of manganese had significantly lower levels of hemoglobin in the blood. This condition seemed to be related to the lower serum iron levels of the lambs on high manganese.

Blakemore et al. (1937) believed that lactation tetany in cows and sheep was associated with the temporary lowering of blood magnesium as the result of consuming forage particularly high in manganese. Underwood (1940) stated that the manganese content of forages in these lactation tetany areas was approximately 734 ppm.

After testing many forage plants, Bolin (1934) reported that the difference in manganese content of various forages is due to the difference in their capacity to extract manganese from the soil. Monier-Williams (1949) states that not only the amount of manganese in the soil but the availability of the manganese to the plants determines the amount found in the plants. There are several factors which can affect the amount of manganese a plant can obtain from the soil. According to Gooden and Grimmett (1928), the most important factor is lack of drainage. They found that oats grown on poorly drained soil contained six times as much manganese as oats produced on drained soil. Liming the soil was found to be effective in decreasing manganese content of the plants.

EXPERIMENTAL

This experiment was initiated in 1950 at the Lake Carl Blackwell Range Area near Stillwater. The fourth and final year's work is reported here. Originally, 64 grade Hereford cows were divided into four equal lots on the basis of age and previous reproductive performance. After being on the experiment for one year, two cows had to be removed, one from Lot 3 because of a prolapsed uterus, and one from Lot 4 because of enlarged ovaries and a tumor on the uterus. At the end of the second year, one cow from Lot 2 had to be removed because of a spoiled udder, and one from Lot 3 because of a mummified fetus. Two cows in Lot 3 died shortly after calving during the fourth year of the experiment.

The cows of all lots were confined to small traps during the winter season. They received a basal ration of prairie hay (free choice), 1.4 pound of corn gluten meal per head daily, fed on alternate days, and salt, free choice. The cows of Lot 1 (control group) received only the basal ration. The cows of Lot 2 received the basal ration plus 1.68 grams of manganese sulfate[1] per head daily. This amount raised the total manganese content of the ration to approximately 250 ppm. Lot 3 received the basal ration plus 3.97 grams manganese sulfate per head daily, which raised the total manganese content of the ration to approximately 500 ppm. Lot 4 received the same ration as Lot 3 plus a

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

supplement of 400 mg. of iron as ferrous sulfate and 40 mg. of copper as copper sulfate per head daily. The prairie hay contained approximately 68 ppm. manganese. During the winter period the minerals were mixed with corn gluten meal and fed in a trough.

During the summer grazing period, the cows of all lots were allowed to graze native grass pasture. Salt (free choice) was provided at all times. During the pasture season the supplemental minerals (manganese for Lots 2 and 3, and manganese, iron and copper for Lot 4), were mixed with corn which was fed at the rate of one pound per head per day, on alternate days. The cows of Lot 1 received no supplemental minerals and at no time during the trial was supplemental phosphorus fed to any of the cows in the experiment.

Bulls were placed with the cows on May 1, and removed September 1. To minimize sire differences, they were rotated among the lots. The calves were weaned on October 12, 1954, when they were seven to eight months of age.

Blood samples for determination of blood plasma phosphorus, plasma protein, hemoglobin, hematocrit, and red blood cell count were taken at regular intervals from one half of the cows in each lot. Individual weights of cows and calves were obtained at the time blood samples were taken.

The experiment was terminated on October 20, 1954. Forty of the cows were slaughtered and inspected for gross anatomical abnormalities. Liver and bone samples were taken for further study.

The method used in the determination of the manganese content of the livers was a modification of the method of Willard and Greathouse (1917).

The following procedure was used to obtain the bone measurement data. One fore leg of each cow was removed at the proximal end of the metacarpus and was stored in a freezing room until samples could be taken. The bones were later thawed and allowed to dry for approximately 24 hours. The meat and tendons were stripped back with the aid of a knife to expose the large metacarpal bone which was removed from the foot at the carpus joint. The large metacarpal was then scraped clean with a knife. The mid-point of each bone was found with a ruler and two adjacent one-inch cross sections were taken at this point, by the use of an electric meat saw. Three measurements of bone wall thickness were taken with a micrometer at each side of the mid-point of the bone. Three measurements were taken of the wall thickness of each section. The six measurements were averaged to give the average thickness of the bone wall of each animal.

RESULTS AND DISCUSSION

Cow Data

The weight data of the cows are summarized in Table I. High levels of manganese apparently had no effect upon weights of the cows. The initial weight of the Lot 3 cows (500 ppm. manganese) was considerably less than that of the other lots because of very small summer gains the second year; however, this group of cows made an average yearly gain of 39 pounds as compared to yearly losses of 33, 12, and 28 pounds for Lots 1, 2, and 4, respectively. This observation is very similar to the results reported by Swader (1955), who found that Lot 3 was the only lot which showed a net gain during the third year. The weight changes of the cows were variable from year to year, and were not consistent enough to be related to the manganese level. Because of their lower initial weight and thinner condition, the Lot 3 cows would probably be expected to gain more weight than the cows of the other lots. If manganese does exert an adverse effect on gain in weight, possibly tolerance to high levels was built up by the cows of Lot 3.

The effects of the addition of iron and copper to a high manganese ration were not clear-cut. Russell (1947) had reported an anemia among horses that grazed areas in which the forages contained high levels of manganese, whereas in areas where the manganese level was normal no anemia was noted. No symptoms of anemia were observed in the present experiment, and beneficial effects of the iron and copper could not be seen in this data because of the increased gain of Lot 3 over the other lots. On the other hand, the lots which received supplemental manganese without the addition of iron and copper (Lots 2 and 3) had average final weights which were lower than the other lots. However, these differences in weights were small and probably could not be related to the treatments.

No consistent abnormalities, which could be related to treatment, were observed when the cows were slaughtered. However, it should be pointed out that the mortality rate of cows was higher in those lots which received supplemental manganese. Of the original 16 cows which started in each lot, all 16 cows of Lot 1 (control) finished the trial, while three cows from Lot 2, four from Lot 3, and two from Lot 4, either died or had to be removed for various reasons during the four years of the experiment. This difference in outcome suggests a possible detrimental effect of a high manganese intake.

Production Data

A summary of the production data is given in Table I. Calf production was reduced in Lot 1 by the death of a calf at birth, in Lot 3 by the death of two cows and one additional calf at calving time, and in Lot 4 by two premature births and the death of another calf at castration. The calf losses and mortality rate of the cows were higher in the lots receiving manganese. This is in agreement with the findings of Blucker (1953) and Swader (1955) in the second and third years of this study. Further indication that the high levels of manganese might be adversely affecting the reproductive performance of the cows was seen from a pregnancy check of the cows that were slaughtered. All of the cows in Lot 1 were pregnant while five cows in Lot 2, two in Lot 3, and two in Lot 4 were open.

TABLE I

SUMMARY OF COW WEIGHTS AND PRODUCTION 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 (11-10-53)	16	13	14[4]	15
Average weight of cows (lbs.)				
Initial 11-10-53	1115	1062	983	1107
Before calving 1-20-54	1088	1100	1014	1110
End of winter feeding 4-21-54	871	963	922	863
Final 10-20-54	1082	1050	1022	1079
Average weight change of cows (lbs.)				
Winter change to calving	-27	38	31	3
Winter loss	-244	-99	-61	-244
Summer gain	211	87	100	216
Yearly gain or loss	-33	-12	39	-28
Birth weight of calves[1]	80	76	78	77
Number of calves weaned[2]	15[3]	13	11[4]	12[5]
Average weaning weight of calves 10-12-54	459	450	456	457

[1]Corrected for sex by adding 5 lb. to the actual birth weight of each heifer.
[2]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 lb. to the age corrected weight of each heifer.
[3]One calf died at birth.
[4]Two cows died shortly after calving, one additional calf died at birth.
[5]Two calves born prematurely, another died at castration.

The differences in birth weight of calves among the four lots were so small that they were not considered important or related to treatment. The differences in weaning weight were also very small. Lot 1 averaged 9 pounds more than Lot 2, 3 pounds more than Lot 3, and 2 pounds more than Lot 4. These differences were not statistically significant. Nelson (1952) and Swader (1955) in the first and third year of this experiment also failed to find any significant difference in weaning weight. On the other hand, Blucker (1953) found a significant difference in weaning weights the second year. A consideration of all four years of this work reveals no marked or constant effects of high levels of manganese on weaning weights of calves.

Blood Data

A summary of the blood analysis is shown in Table II. The average blood plasma phosphorus values of the cows showed considerable variation throughout the year. No marked and consistant difference among the lots could be seen; although Lot 1 tended to have the lowest phosphorus value. This does not agree with previous work by Blucker (1953) and Swader (1955) who found that Lot 3 consistently had lower values than the other lots.

Plasma phosphorus values were very low during the winter, dropping to an average of 1.63, 2.90, 2.70, and 2.05 for Lots 1, 2, 3, and 4, respectively, during April. The average plasma phosphorus value for all lots was less than 3.00 mg. per 100 ml. of plasma during the months of February and April. Values this low are considered to represent a critical state of phosphorus nutrition. Maynard (1947) and Huffman (1933)

TABLE XI

BLOOD CONSTITUENTS OF SOWS

Lot	11-10-53	2-3-54	4-21-54	6-8-54	7-9-54	9-2-54	10-12-54	Average
				Phosphorus (Mg. per 100 ml. plasma)				
I	5.33	2.53	1.63	3.00	3.73	3.12	4.82	3.30
II	5.68	2.50	2.90	5.56	4.76	3.84	3.81	4.15
III	5.72	2.53	2.70	4.62	5.34	4.31	2.84	4.09
IV	3.98	2.45	2.05	5.07	2.70	5.42	3.46	3.59
				Hemoglobin (Gm. per 100 ml.)				
I	11.8	11.1	10.4	10.7	10.5	12.3	10.1	11.0
II	11.0	11.1	10.0	10.7	10.8	11.8	10.9	10.9
III	10.8	10.3	10.0	10.9	11.1	11.5	10.5	10.7
IV	11.6	11.2	10.3	11.6	11.3	12.1	11.0	11.3
				Hematocrit (Volume per cent)				
I	26	34	31	30	33	36	31	33
II	34	33	31	31	33	35	32	33
III	33	31	31	31	30	33	31	32
IV	36	35	31	34	35	33	33	34
				Plasma Protein (Gm. per 100 ml.)				
I	7.61	8.14	7.84	8.52	8.68	8.48	7.75	8.15
II	7.26	7.54	8.01	8.30	8.38	7.74	7.31	7.79
III	7.61	7.93	7.92	8.64	8.31	8.49	7.55	8.07
IV	7.92	8.33	7.72	8.33	8.38	7.80	7.64	8.03
				Red Blood Cells (Millions per cu. mm.)				
I	7.53	6.49	6.35	5.94	5.94	7.20	5.88	6.48
II	6.80	6.55	5.94	5.78	5.87	6.85	6.46	6.32
III	6.63	6.20	6.11	6.24	6.11	6.61	6.10	6.30
IV	7.13	6.71	6.03	6.68	6.80	7.08	6.27	6.67

stated that plasma phosphorus below 4.00 mg. per cent gave indication of a pending aphosphorosis. However, Knox *et al.* (1941) reported that range beef cows remained healthy and reproduced normally when their plasma phosphorus levels dropped as low as 2.00 mg. per cent for short periods. No symptoms of phosphorus deficiency were observed during the year, so these results agree with work reported by Knox.

The beginning of the grazing season brought a considerable rise in the blood phosphorus values; average value of 3.00, 5.56, 4.68, and 5.07 mg. per cent for Lots 1, 2, 3, and 4, respectively, being reached during July. There was still considerable fluctuation in blood phosphorus values among the lots throughout the summer grazing period. It should be pointed out that except for one year, the cows were rotated among the pastures, and that the lowest blood phosphorus values, most frequently, came from the cows which had previously grazed one particular pasture, which was designated in this experiment as pasture No. 1. This condition of low blood phosphorus and also correspondingly low gains of cows while grazing pasture No. 1 was observed by Blucker (1953) and Swader (1955) in the second and third years of this work. This might account for the small summer gains of Lot 3 during the second year, because during that year the Lot 3 cows remained in pasture No. 1 throughout the summer grazing season. Differences were not found in chemical composition of the forage of the pastures, but apparently there is some unknown factor associated with pasture No. 1 which is causing these low values.

Differences in hemoglobin, hematocrit, plasma protein, and red blood cell count were very small and could not be related to the treatments.

Liver Data

The manganese content of the livers of the cows which were slaughtered is shown in Table III. It should be noted that the highest values were from the lots receiving supplemental manganese. Lots 1, 2, 3, and 4 had average values of 2.45, 2.91, 2.93, and 2.66 ppm., respectively.

TABLE III

MANGANESE CONTENT OF LIVERS

Lot 1		Lot 2		Lot 3		Lot 4	
No supplemental manganese		250 ppm. manganese		500 ppm. manganese		500 ppm. manganese, iron, and copper	
Animal	Mn (ppm.)	Animal	Mn (ppm.)	Animal	Mn (ppm.)	Animal	Mn (ppm.)
1-7*	—	6-7	2.85	3-7	3.22	5-7*	—
3	2.34	5*	—	8-7	2.61	12	2.94
43	2.38	10*	—	7	2.67	51	1.96
47	2.18	11*	—	41*	—	57	3.09
59	2.61	18	2.57	121	3.05	122	2.11
115	1.75	26	3.63	137	2.95	127	2.82
117	3.87	114	2.65	145	2.99	147	2.97
118	2.04	116	2.43	149	3.43	155	2.88
124	2.61	120	3.19	154	2.54	163	2.30
140	2.70	170	2.79			176	2.91
153	2.48	171	3.15				
157	1.95						
160	2.53						
Average	2.45		2.91		2.93		2.66

* Sample lost

The differences among lots were not statistically significant ($P < 5$ per cent). These results indicate that the manganese content of the liver may be related to the state of manganese nutrition. It also might be used as a measure of manganese storage in the body because manganese is stored primarily in the liver. Grummer (1950), in work with swine, found that the amount of manganese stored was not proportional to the level fed, but there was a tendency for manganese to concentrate in the livers of pigs when they were fed rations containing additional manganese.

The fact that the differences in liver manganese among the lots were small, would indicate that a high level of excretion takes place in cattle receiving supplemental manganese. According to Nance (1952) the fecal manganese is roughly proportional to the amount of supplemental manganese fed.

Bone Data

A summary of the bone measurements is shown in Table IV. The differences in thickness of wall of the large metacarpal bone, among the lots, were very small and not statistically significant. The average thickness was 6.1, 5.9, 6.0, and 5.9 mm. for Lots 1, 2, 3, and 4, respectively. Reid (1947) stated that the addition of manganese sulfate to a ration for dairy cows increased the calcium excretion until a negative calcium balance existed. Nance (1952) reported that high levels of manganese increased the fecal excretion of calcium and phosphorus by steers. A similar effect is indicated in the work of Chornock et al. (1942) with rats.

When conditions of this nature are severe enough or last long enough, decalcification of the bones usually occur. In the present experiment, there was no evidence of decalcification despite low intakes of phosphorus, relatively high intakes of calcium from forage and different amounts of manganese.

TABLE IV

THICKNESS OF THE DIAPHYSIAL WALL OF THE LARGE METACARPAL BONE

Lot 1		Lot 2		Lot 3		Lot 4	
No supplemental manganese		250 ppm. manganese		500 ppm. manganese		500 ppm. manganese, iron, and copper	
Animal	mm.	Animal	mm.	Animal	mm.	Animal	mm.
1-7	6.1	5	6.5	7	6.0	12	6.2
3	6.3	6-7	5.8	3-7	7.2	51	5.9
43	6.8	10	5.4	8-7	4.9	57	5.5
59	6.2	18	5.7	121	6.8	122	5.4
115	5.9	26	6.2	145	5.3	127	6.0
124	6.3	114	5.6	149	6.4	147	6.2
140	5.0	116	5.6	154	5.7	155	6.2
153	5.9	120	5.7			163	6.2
160	6.3	170	5.6			176	5.7
118	6.8	171	7.0				
117	5.5	11	5.9				
47	6.7						
Average	6.1		5.9		6.0		5.9

SUMMARY

An experiment was started in 1950 at the Lake Carl Blackwell Range Area near Stillwater to study the effects of high manganese intake on beef cattle. Sixty-four Hereford cows were divided into four equal lots on the basis of age and previous reproductive performance. During the winter, all cows were confined to small traps. They received a basal ration of prairie hay (free choice), and 1.4 pounds of corn gluten meal per head daily. Loose salt was provided at all times (free choice). Cows of all lots grazed native grass pastures during the summer grazing period. Lot 1 served as the control lot and received only the basal ration. Lot 2 received the basal ration plus manganese sulfate to raise the manganese content to 250 ppm. Lot 3 received the basal ration plus manganese sulfate to raise the manganese content to 500 ppm. Lot 4 received the same ration as Lot 3 with the addition of 400 mg. of iron and 40 mg. of copper per head daily.

The fourth and final year's work of this experiment may be summarized as follows.

1. Differences among the lots in weight changes of the cows were small and could not be associated with the treatments.

2. No consistent abnormalities of the cows were found at the time of slaughter. The mortality rate of the cows was higher in the lots which received supplemental manganese.

3. Differences in birth weights and weaning weights among the

calves were not significant. However, there was an increased death loss of calves at calving time in Lots 3 and 4.

4. The plasma phosphorus level of all the cows was very low during the winter, but the cows showed no other symptoms of phosphorus deficiency. Differences between lots in plasma phosphorus values in both the winter and summer season were small and inconsistent.

5. Differences in hemoglobin, hematocrit, plasma protein, and red blood cell count among the lots were small, and apparently not influenced by treatments.

6. Cows fed high levels of manganese stored more manganese in the liver than did cows fed no manganese. Differences were not statistically significant.

7. Differences between lots in thickness of bone wall were too small to be significant.

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APPENDIX

TABLE V

ANALYSIS OF VARIANCE OF CALF WEIGHTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	50	90677	1814
Treatment	3	653	218
Error	47	90024	1915

TABLE VI

ANALYSIS OF VARIANCE OF THE MANGANESE CONTENT OF COW LIVERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	36	7.82	.22
Treatment	3	1.52	.51
Error	33	6.30	.19

TABLE VII

ANALYSIS OF VARIANCE OF THICKNESS OF WALL OF METACARPAL BONE

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	37	11.1	0.300
Treatment	3	0.3	0.100
Error	34	10.8	0.318

VITA

Jack Wesley McAskill

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF HIGH LEVELS OF MANGANESE INTAKE ON THE PERFORMANCE OF BEEF COWS

Major: Animal Husbandry

Biographical and Other Items:

Born: March 8, 1930, at Stillwater, Oklahoma.

Undergraduate Study: Oklahoma A. and M. College, 1948-1950; 1952-1955.

Graduate Study: Oklahoma A. and M. College, 1955-1956.

Experiences: Farming and ranching experience; laboratory assistant in Photography Department at Oklahoma A. and M. College; served two years in the Army; Graduate Student Research Assistant in the Agricultural and Developmental Department for Charles Pfizer Chemical Company.

Date of Final Examination: May, 1956.

THESIS TITLE: THE EFFECT OF HIGH LEVELS OF MANGANESE INTAKE ON THE PERFORMANCE OF BEEF COWS

AUTHOR: JACK WESLEY MCASKILL

THESIS ADVISER: DR. ROBERT TOTUSEK

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