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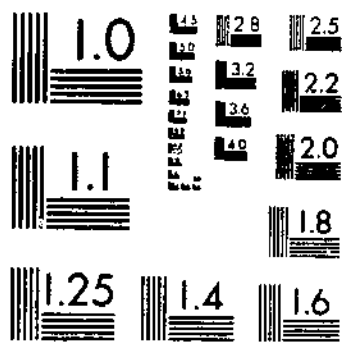
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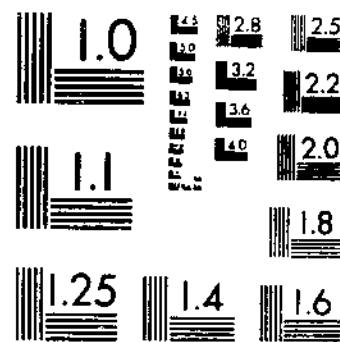
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UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Effects of Phosphorus Supplements on Cattle Grazing on Range Deficient in This Mineral¹

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INTRODUCTION

In the main, if beef cattle receive a variety of feeds, including legume hays, cereal grains, protein concentrates, and common salt (sodium chloride), there is little likelihood of mineral deficiencies in the ration. Grains and other highly concentrated cattle feeds in general are good sources of phosphorus, and legumes are rather high in calcium. These two minerals constitute the greater part of the mineral constituents of the animal body. However, a large percentage of the cattle in the United States never get legume hays and grains but must subsist on native vegetation, much of which is low in minerals.

Lack of phosphorus is one of the major nutritional deficiencies in many of the beef-producing areas, particularly in the Southern States. There may be deficiencies in several of the other essential mineral elements and in protein or carotene, but they do not appear to be so widespread as that of phosphorus. The habit of chewing bones and stiffness in the forequarters accompanied by emaciation indicate a phosphorus deficiency in the animal.

For years beef producers on the South African veld were confronted with small-percentage calf crops and in many instances with severe

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death losses among mature cattle. In 1924 Theiler, Green, and Du Toit (8)² identified the trouble as a phosphorus deficiency and called this condition aphosphorosis. The first symptom of such a deficiency is usually a perverted or depraved appetite as evidenced by the chewing of wood, bones, and miscellaneous materials. When the disease advances to the stage at which the development of the body or growth is materially impaired, it is known as styfsiekte in South Africa, stiffs or sweeny in Florida, and creeps in Texas and other localities. In very advanced stages the appetite becomes so depraved that cattle frequently eat carcass debris containing toxins produced by the organism *Clostridium botulinum bovis*, resulting in a disease known in South Africa as lamsiekte (1), which usually proves fatal. This condition is probably identical with that known in the United States as loin disease.

In South Africa, where mineral metabolism of cattle has been one of the foremost nutritional subjects of investigation for many years, Du Toit and Bisschop (2) obtained significant results from the feeding of bonemeal to breeding cows grazing on phosphorus-deficient veld. In the experiment, cows and heifers in calf and lactating cows were fed 5 ounces of bonemeal daily (except Sundays), and all growing and dry stock were fed 3 ounces. The calves were fed the bonemeal supplement from weaning at 9 months of age until they were 30 months old. In these investigations the bonemeal supplement, when fed in small quantities, not only prevented lamsiekte, but also was responsible for a remarkable rate of growth and improvement in condition. Bonemeal was found to have a marked influence on the fertility of the cows, caused them to breed with much greater regularity, and significantly increased the milk flow. This in turn favored increased growth and skeletal development of the calves.

A lactating cow on a ration containing insufficient phosphorus to meet her requirements for maintenance and production usually draws on the phosphorus stored in her skeleton in an effort to maintain a normal supply of milk for her calf. Occasionally, instead of the system being drained of phosphorus, the milk flow is reduced, resulting in a stunted calf. A continued drain of the skeletal phosphorus results in fragile, incompletely ossified bones, lameness, and death in many cases.

Further experiments by Theiler, Green, and Du Toit (9) showed that the inorganic phosphorus content of the blood of an animal indicates whether it is receiving adequate phosphorus. The phosphorus content of blood of cattle receiving sufficient phosphorus varies from 4 to 9 mg. per 100 cc. of blood, depending on the age of the animal; the younger the animal, generally speaking, the higher the phosphorus content. In phosphorus deficiency the phosphorus content of the blood decreases. The method of Mahan and Van Der Linde (5) for determining the phosphorus and other minerals through blood chemistry and the detection of mineral deficiencies through such analyses has contributed much to the livestock industry of South Africa. Similar methods are being used rather extensively by scientists in the United States and other countries for locating areas of mineral-deficient soils and the extent of the deficiencies.

² Italic numbers in parentheses refer to Literature Cited, p. 23.

Malan, Green, and Du Toit (4) found that when heifers grazing on phosphorus-deficient pasture were fed bonemeal from the age of 9 months to 2 years, they maintained a normal content of 5 mg. of phosphorus per 100 cc. of blood, whereas control heifers had only half that amount. Investigations conducted in the Gulf coast region of Texas by Schmidt (6) showed that mixtures of bonemeal and common salt fed to range cattle increased gains in weight during a favorable season, produced stronger calves, prevented creeps, and reduced losses from diseases other than those of an infectious character. The feeding of salt with the bonemeal increased the palatability of the latter, as cows offered bonemeal alone for the first 2 months of the test refused to eat it. After 2 parts by weight of common salt was added to 3 parts of bonemeal, the mixture was eaten readily. Finely ground rock phosphate, when fed alone or when mixed with salt or when mixed with salt and bonemeal in equal parts, did not give satisfactory results.

Bekker (7) in South Africa reports experiments showing two-thirds of an ounce of dicalcium phosphate to be as effective as 3 ounces of bonemeal or 2 ounces of disodium phosphate (20-percent phosphorus pentoxide). Dicalcium phosphate is only slightly soluble in water and should be hand-dosed or mixed with common salt or a palatable feed. Disodium phosphate is soluble in soft water and may be placed in the drinking water, but this can be done satisfactorily only when the cattle are compelled to get their water from a supply treated with that mineral. The addition of disodium phosphate to hard water, which usually contains appreciable quantities of calcium and magnesium, results in the precipitation of phosphates. In Bekker's experiment, therefore, 1 cc. of 90-percent commercial sulfuric acid was added to each gallon of hard water to obtain complete solution. A trace of copper sulphate (1 in 250,000) was added to the water also to inhibit the growth of algae. This experiment showed that when disodium phosphate was dissolved in the water supply at the rate of approximately 45 gm. per 6 gallons of water, the cattle drank 5.8 gallons each per day and thus obtained 1.56 ounces of disodium phosphate, or 10.08 gm. of phosphorus pentoxide.

In 1931, under an agreement between the Bureau of Animal Industry of the United States Department of Agriculture and the King Ranch, Kingsville, Tex., the senior author of this bulletin was sent to the Union of South Africa to observe methods of range-cattle production. He reported on the excellent results obtained by the South African investigators in their mineral-metabolism studies, in which cattle grazing phosphorus-deficient ranges were supplied with this mineral. Representatives of the Bureau of Animal Industry, the Texas Agricultural Experiment Station, and the King Ranch concurred in the opinion that the results of the phosphorus-deficiency studies in South Africa would apply to vast areas of range country in the South and Southwest and entered into a cooperative agreement in 1937 to study the phosphorus problem in southern Texas. The cattle, fenced areas of range land, scales, supplemental mineral feeds, and the labor required for conducting the experiments were provided by the King Ranch. The Bureau of Animal Industry and the Texas Agricultural Experiment Station supervised the project, collected and analyzed the forage and blood samples of the animals, and were responsible for the technical phases of the experimental work in general.

THE AREA AND ITS PROBLEMS

The area wherein the present investigations were conducted is the nearly flat coastal plain of Texas bordering on the Gulf of Mexico. Climatic conditions vary from humid in the eastern part of the area to subhumid in the western part, and soil types vary from heavy clays to fine sands. The native vegetation consists principally of species of *Andropogon* (sage grasses and bluestem), *Paspalum* (Georgian or honeydew grass predominating), *Sporobolus* (smutgrass predominating), *Panicum*, *Elyonurus tripsacoides* (joint grass), and *Aristida* (three-awn). Also there are species of *Stipa*, *Setaria*, *Eragrostis*, *Axonopus affinis* (carpet grass), and others of less importance. *Cynodon dactylon* (Bermuda grass) is often associated with these taller grasses. A narrow, marshy fringe bordering the coast is populated principally by the saltgrasses (*Spartina* species). The heavier soils in the subhumid region of the western part of the area are covered mostly by the shorter grasses, such as *Hilaria belangeri* (curly mesquite), *Buchloe dactyloides* (buffalo grass), and *Bouteloua* species (grama grasses), and by shrubs with mesquite (*Prosopis chilensis*) predominating.

The abundance of vegetation on the pastures of the area has resulted in greater numbers of cattle per section than in other range areas of the State. However, many of the cattle are comparatively small and in poor condition and most herds have failed to reproduce normally. The animals have been much improved by careful selection and breeding, but they still fail to attain the skeletal development or condition of cattle raised in other sections unless feed other than the natural pasturage is provided. Other evidences that a nutritional deficiency is present in the vegetation are the small calf crops; a persistent craving by many cattle for bones, dirt, wood, and other materials; malformed bones that often are easily broken; and the occurrence of creeps, a severe form of aphosphorosis that usually occurs among lactating cows. The animals affected with this deficiency disease become thin and weak and move with a peculiarly stiff, creepy gait.

The investigations reported in this bulletin were designed to study (1) the extent of phosphorus deficiency in the vegetation in southern Texas and (2) methods of correcting the deficiency by administering phosphorus supplements to the cattle grazing range deficient in this mineral. A study of the effect of the phosphorus supplement on beef production and reproduction was the principal object of the investigation.

PRELIMINARY INVESTIGATIONS

Preliminary studies were made in 1937 in cooperation with the Texas Agricultural Experiment Station to determine what elements necessary for the proper nutrition of cattle were deficient in the vegetation of the area, and also to locate a definite phosphorus-deficient range for use in conducting feeding tests. This work consisted in the collection of samples of forage from representative pastures in 15 counties throughout southern Texas, chemical analysis of these samples to determine their protein, calcium, and phosphorus contents, observation of cattle subsisting on this vegetation for evidences of nutritional deficiencies, and occasional analyses of blood samples of such cattle

to determine the inorganic phosphorus content of their blood. The results of the chemical analyses of the samples are reported in table 1.

The most important information indicated by the analyses of vegetation collected in the preliminary studies was that a phosphorus deficiency of considerable consequence existed in the native range vegetation of practically all the area studied and that the calcium content was apparently sufficient. Few of the samples contained more than 0.12 percent of phosphorus, and few had a calcium content of less than 0.24 percent. A phosphorus content of 0.13 percent and a calcium content of 0.23 percent of the dry matter of the vegetation consumed have been generally accepted as the minimum amounts of these elements required by range cattle and are compar-



FIGURE 1.—The emaciated condition of this cow indicates the presence of creeps, one of the common forms of aphosphorosis.

able with those reported by Fraps and Fudge (3). Another point to be considered is that the phosphorus content of vegetation is reduced as the plants mature or become dry, whereas variations in calcium content appear not to be caused by the stage of growth. Most of the samples collected were in the green state. It was also found that considerable differences exist in the composition of different species and in the same species in different localities and also that a low protein content of the forage is usually associated with a low phosphorus content.

Bone chewing and other less common evidences of nutritional deficiency were observed throughout southern Texas. Instances of creeps were common, and this malady often reached alarming proportions in periods of drought. Cattle suffering from this disease (fig. 1) were observed to spend less time in grazing than normal animals. This fact may be attributed either to loss of appetite for the forage or to pain involved in moving about during grazing.

Inorganic phosphorus determinations of blood samples from cattle in several pastures verified the analyses of the grass samples as to the low phosphorus content of the forage.

As a result of these preliminary studies a definite phosphorus-deficient range area was located in the Nueces fine-sand type of soil in southern Texas. The predominating grasses were *Paspalum plicatulum* (honeydew or Georgia grass), *Andropogon littoralis* (blue sage grass), *Elyonurus tripsacoides* (joint grass), *Aristida purpurea* (purple three-awn), and *Paspalum setaceum*. Of much less importance were *Eragrostis secundiflora*, *Bouteloua hirsuta* (hairy grama), *Brachiaria ciliatissima*, *Spartina spartinae* (big saltgrass or sacahuista), *Sporobolus purpurascens*, *Prosopis chilensis* (mesquite), and *Acacia greggii* (catclaw), which furnished some grazing during certain seasons.

FEEDING EXPERIMENTS

PROCEDURE

To determine the effects of supplying phosphorus to cattle grazing on range deficient in this mineral, experiments were conducted from January 1938 to March 1941, inclusive, in the southern part of Brooks County, Tex., on what is known as the Encino Division of the King Ranch. Samples of the species providing the greater part of the forage were collected each month during the experiment and analyzed for protein, calcium, and phosphorus contents to study the relation of the nutritive value of the vegetation to rainfall and cattle gains.

For the mineral-feeding experiments, 100 Brahman \times Shorthorn and Brahman \times Hereford heifers approximately 18 months of age were selected (fig. 2). They were divided as equally as possible, with respect to weight, quality, and breeding, into 4 groups of 25 head each. All groups utilized the same pasture and water supply (fig. 3) and were allotted to the same bulls. Santa Gertrudis bulls at the rate of 1 per 20 cows remained in the pasture from March 1938 until the completion of the experiment. The original groups of cows remained in the experiment until 2 calf crops were weaned. All suitable heifer calves were retained and, when 18 months old, were placed with the bulls. These replacement heifers after weaning were fed the same mineral supplements as their dams.

To avoid any possible differences in the consumption of mineral supplements among the animals in a group, the heifers were put through a chute early each day (except Sunday) and were fed the mineral supplement by hand-dosing (fig. 4). The control group, receiving no mineral supplement, was put through the chute with the mineral-fed groups in order that all groups would be handled alike except for supplement feeding. Supplement feeding of each group was as follows:

Group 1.—No supplement.

Group 2.—Bonemeal in sufficient amounts to provide the dry cows and heifers with 6.5 gm. of phosphorus and approximately 13 gm. of calcium and the lactating cows with 14.3 gm. of phosphorus and approximately 28.5 gm. of calcium per head daily.

Group 3.—Disodium phosphate to provide the dry cows and heifers with 6.5 gm. of phosphorus and the lactating cows with 14.3 gm. of phosphorus per head daily.



FIGURE 2.—A group of the heifers used in the experiments. Photographs taken shortly after the beginning of the study in 1938.



FIGURE 3.—Equipment used in the experiment. The range used is in the background.

Group 4.—Bonemeal to provide all cows, both dry and lactating, and heifers with the same quantities of phosphorus and calcium as were fed to the dry cows and heifers of group 2; in addition, minerals to supply 160 mg. of iron, 100 mg. of manganese, and 15 mg. each of copper, cobalt, zinc, and boron.



FIGURE 4.—Administering a phosphorus supplement by hand-dosing.

Except for a few periods, all experimental cattle were weighed at intervals of 28 days throughout the test. Calves were weaned at an average age of approximately 293 days, at which time the steers were eliminated from the groups.

The range used in this experiment was moderately stocked, the rate being one breeding animal per 10 acres. The same range was used continuously throughout the entire experiment. As heifers were weaned, they were kept in a separate pasture from their dams until they were 18 months of age. During the experiment the original tract was enlarged in proportion to the number of heifers retained for the experiment. Common salt was available in self-feeders, but very little was consumed.

At 14-day intervals, blood samples were collected from a representative number of cows and from their calves if the cows were lactating. The amount of inorganic phosphorus and, after September 10, 1938, the amount of hemoglobin in each sample were determined. The former determinations were made by the method described by Malan and Van Der Lingen (5). The hemoglobin determinations were made by the Newcomer method. Samples were collected 80 times during the course of the experiment.

ANALYSES OF GRASSES

As shown by table 1, the analyses of the grass samples from the experimental pastures from 1938 to 1941, inclusive, were similar to those during the preliminary investigations in 1937. In only a few instances was the calcium content below 0.23 percent or the phosphorus content above 0.13, thus indicating sufficient calcium but a deficiency of phosphorus. The protein content of most of the species analyzed tended to be lowest during winter and drought periods, when there was the least green feed. This was likewise true of phosphorus. The effect of rainfall was usually reflected in increased percentages of phosphorus in the months immediately following the heaviest precipitation (fig. 5). However, the figure shows that changes in calcium content usually were not related to the amount of rainfall. A comparison of the precipitation data in figure 5 and the weights of cows in figure 6 shows that there is a definite trend toward increase or decrease in gains of the animals about 1 month after the periods of heaviest or lightest rainfall. For example, the marked decline in gains from about December 1, 1939, to March 20, 1940, was due to a severe drought. After a rainfall of 2.25 inches in March, there was a marked rise in gains in weight of the animals from March 21 to November 1.

A comparison of the rainfall data with the phosphorus content of the blood samples taken from the experimental cows each month (fig. 12) reveals an upward trend in blood phosphorus after the periods of heaviest rainfall. In other words, when the plants received the required moisture, the vegetative growth was stimulated materially and this increased growth of grass, together with a somewhat increased percentage of phosphorus, enabled the cattle to get a fill of forage that was more nutritious than during dry seasons, resulting in a phosphorus build-up in the blood.

TABLE 1.—Average protein, calcium, and phosphorus content, on an air-dry basis, of some of the more important forage plants in southern Texas, and rainfall during the experimental period

[1937 data from representative areas in 15 counties; 1938-41 data from areas grazed by experimental cattle]

Year and month	<i>Paspalum plicatulum</i>			<i>Andropogon littoralis</i>			<i>Elyonurus tripsacoides</i>			<i>Aristida purpurea</i>			<i>Paspalum setaceum</i>			Mixed forage			Rain-fall
	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Inches
1937																			
March	7.95	0.40	0.12	5.62	0.40	0.07	6.34	0.31	0.09	9.15	0.46	0.08							
April	6.26	.37	.08	6.20	.33	.08	6.81	.28	.10	4.80	.26	.06							
May	6.16	.45	.09	6.49	.36	.09	6.87	.33	.09										
June	5.26	.44	.08	5.11	.35	.08	3.87	.28	.07	5.03	.27	.07	9.62	0.67	0.10				
October				4.12	.38	.06				4.25	.24	.04							
November	3.89	.49	.05	3.69	.25	.04	3.82	.32	.04										
1938																			
January	5.86	.48	.06	5.87	.38	.07	7.14	.34	.08	6.73	.33	.13				4.05	0.63	0.13	1.46
February	5.60	.36	.07	6.09	.34	.08	6.92	.26	.08							5.46	.33	.07	1.58
March	7.01	.44	.08	7.30	.36	.09	7.09	.46	.09				8.15	.39	.08	16.52	.54	.16	2.07
April	7.20	.58	.10	6.18	.34	.08	6.51	.28	.09	7.32	.26	.10	7.85	.39	.09				1.05
May	6.43	.48	.07	6.67	.40	.10	5.75	.32	.09				7.25	.70	.09				1.84
June	5.80	.48	.05	4.47	.30	.05	4.88	.34	.04				5.93	.32	.07	6.42	.31	.08	2.51
July	4.70	.49	.06	4.35	.23	.04	4.50	.34	.04				5.38	.53	.05				.00
August	4.31	.36	.04	4.68	.36	.04	3.80	.29	.03	5.55	.26	.06				7.14	.34	.06	5.92
September	7.05	.44	.13	6.03	.31	.15	6.90	.27	.09				8.61	.47	.06	7.88	.27	.10	1.08
October	5.90	.46	.07	5.90	.34	.09	4.87	.25	.07	7.35	.30	.08				6.33	.37	.07	.00
November	5.88	.51	.05	5.25	.30	.06	5.70	.28	.07	6.51	.33	.07							.90
December	4.35	.33	.05	4.53	.29	.05	4.78	.25	.05	6.18	.31	.07							1.75
1939																			
January	5.70	.45	.06	4.03	.27	.05	4.15	.26	.04	5.51	.29	.06				3.88	.32	.03	1.75
February	7.73	.44	.09	5.75	.28	.06	4.26	.25	.05	7.03	.24	.07				8.39	.26	.09	.56
March	9.53	.54	.08	7.26	.36	.10	6.85	.29	.08	7.64	.25	.08	11.95	.54	.10	9.79	.51	.11	.31
April	8.32	.51	.08	6.20	.34	.07	6.07	.30	.07	6.37	.23	.06				15.13	.84	.14	1.84
May	9.25	.50	.10	7.14	.31	.10	6.70	.26	.09	7.92	.24	.10	8.26	.72	.09	6.91	.33	.08	5.62
June	6.48	.46	.07	6.22	.29	.08	5.74	.24	.08				7.70	.34	.10				1.74
July	4.35	.51	.06	4.53	.34	.06	3.62	.22	.05	5.70	.29	.05	5.10	.44	.07	5.84	.24	.07	.40
August	3.67	.49	.05	3.45	.30	.04	3.43	.32	.04	4.41	.24	.07				4.69	.40	.06	.56
September	7.92	.51	.07	7.01	.41	.09	5.85	.29	.07	7.17	.26	.07							4.02
October	7.02	.44	.08	7.19	.30	.09				8.06	.26	.10	9.04	.61	.10				.51
November	4.62	.36	.04	2.88	.26	.05	4.60	.23	.05	5.63	.22	.06	9.33	.55	.12	7.61	.25	.09	.00
December	3.30	.41	.03	4.69	.24	.03	2.91	.23	.03	3.23	.19	.03				3.75	.35	.03	.14

1940																		
January	3.20	.34	.03	3.44	.24	.03	3.18	.24	.04	3.09	.21	.02						.40
February	3.85	.38	.03	3.38	.27	.03	3.24	.21	.03	3.07	.21	.02						.31
March	4.15	.36	.03	3.90	.29	.04	3.48	.20	.03	3.96	.22	.03				16.99	.47	2.25
April	9.55	.54	.11	7.69	.39	.10	9.22	.36	.11	11.29	.23	.11	11.48	.86	.11	13.79	.07	.00
May	5.82	.47	.05	4.06	.26	.04	4.75	.31	.04							14.13	.85	.15
June	8.72	.58	.09	6.94	.34	.08	7.13	.33	.10	7.46	.31	.03	13.64	.63	.12			1.52
July	9.84	.49	.10	6.87	.29	.08	6.76	.29	.07				10.16	.74	.10	12.41	.64	3.75
August	5.73	.20	.08	7.41	.54	.08												2.38
September	9.63	.41	.11				5.27	.27	.06	7.79	.31	.10	9.99	.64	.09			2.92
October	3.83	.30	.05	3.04	.24	.05	3.38	.26	.04							7.53	.82	1.01
November	2.39	.49	.03	3.40	.25	.03	3.66	.33	.04	3.38	.23	.03				7.34	.83	1.10
December	4.76	.33	.04	3.67	.25	.03	4.32	.26	.04							15.18	1.59	2.46
1941																		
January	4.13	.39	.04	3.54	.26	.04				5.11	.27	.05				6.42	.60	.07
February	4.63	.41	.06	4.84	.27	.06	4.56	.24	.05	6.24	.21	.07				8.91	.45	1.68
March	6.15	.44	.08	6.93	.36	.08				7.54	.38	.09	7.98	.60	.11	10.51	1.05	5.32

WEIGHTS AND GAINS OF BREEDING FEMALES

Figure 6 shows graphically the average weights of the cows in the various groups at about 28-day intervals.

In the first 11 months of the test, or until the heifers began calving, there were advantages in average gain in weight of 78 pounds, 108 pounds, and 85 pounds for the heifers of groups 2, 3, and 4, respectively, over that of group 1, the controls. These increased gains were highly significant ($p < 0.01$), according to the methods of Snedecor (7). The mineral-fed heifers, as a whole, made a consistently more rapid gain than the controls from the beginning of

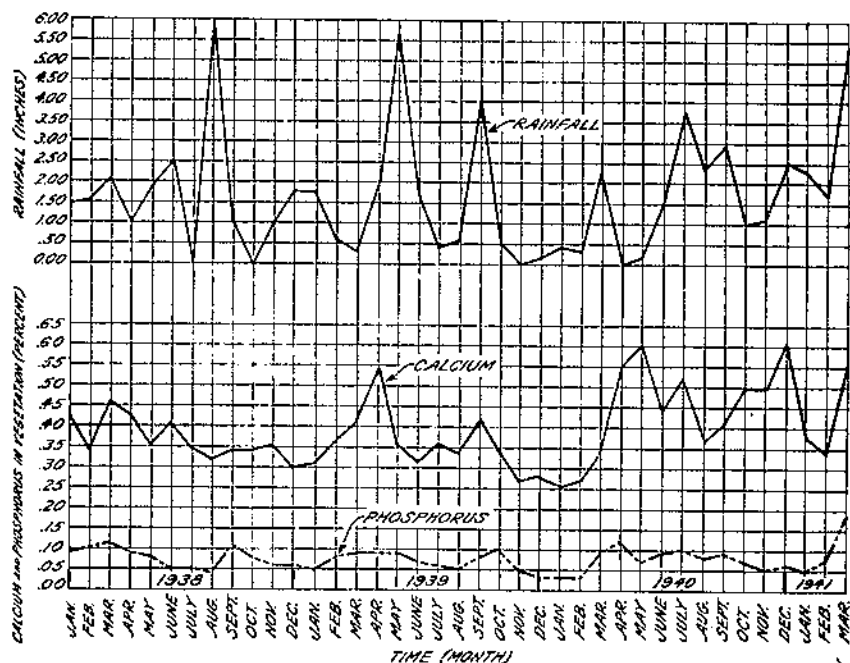


FIGURE 5.—Relation between average monthly rainfall and percentages of calcium and phosphorus in vegetation.

the experiment until the end of 8 months (figs. 7 and 8), after which there was a tendency for differences in rate of gain to become less. At the end of 2 years, the three groups of cows receiving supplemental minerals weighed on the average 98 pounds more per head than the control group, the difference being highly significant. However, at the end of the third year the cows in the control group had essentially the same average weight as those in groups 3 and 4 and only 29 pounds less than that in group 2. This result is attributed to more dry cows in the control group, owing to the fact that many of the cows did not produce calves, under which conditions they tend to fatten readily under favorable range conditions. At the end of the experiment, the average weight per cow in the mineral-fed groups was 46 pounds more than for the cows in the control group.

Differences between the supplement-fed groups were not significant at any time during the experiment, but the average weights of the cows in each of these groups were significantly higher than the weights of the controls at all times except during the last 4 months of the third year. The total gains of the supplement-fed groups were essentially the same for the entire experimental period and averaged 53 pounds more per head than that of the controls, which was significant ($p < 0.05$).

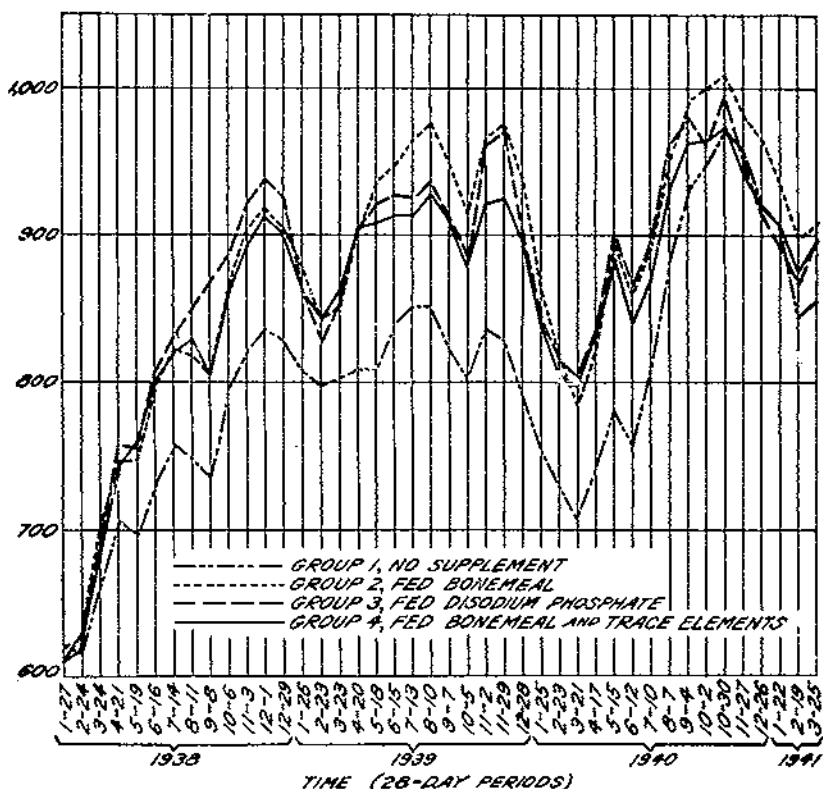


FIGURE 6.—Average weights of cows by groups for each 28-day period.

CALF-PRODUCTION DATA

A summary of the 1939 and 1940 calf-production data for each group of cows is given in table 2. The principal advantage in feeding mineral supplements to breeding cows is the production of more pounds of calf at weaning time, owing not only to heavier calves but also to greater numbers of calves because of a higher percentage calf crop. Figure 9 shows the improved condition of a breeding animal and her calf as a result of feeding a phosphorus supplement.

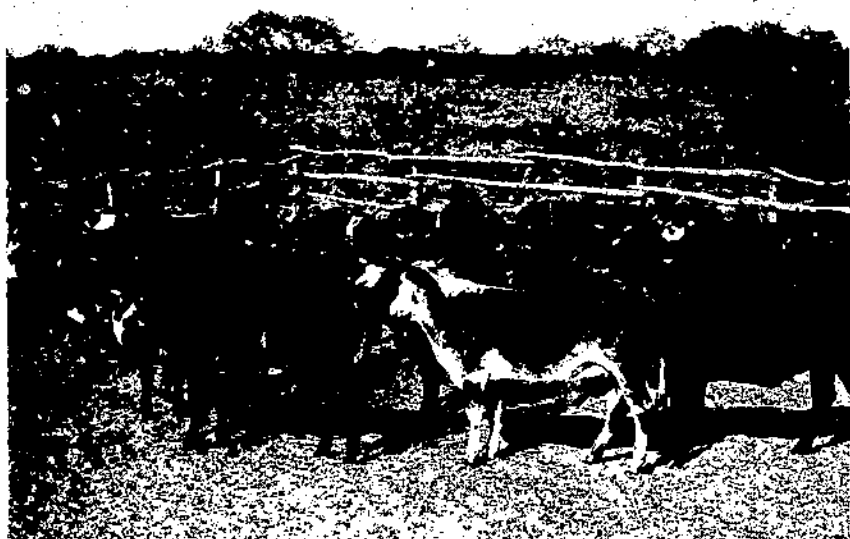


FIGURE 7.—Two-year-old heifers in group 3 after having been fed disodium phosphate for 8 months.



FIGURE 8.—Two-year-old heifers in group 1 (controls) at the end of the first 8 months of test.

TABLE 2.—Production data for the 2 calf crops, 1939 and 1940

Item	Group 1 (controls), fed no supplement		Group 2, fed bonemeal		Group 3, fed disodium phosphate		Group 4, fed bonemeal and trace minerals	
	1939	1940	1939	1940	1939	1940	1939	1940
Cows..... number.....	25	23	25	24	24	23	25	22
Calves born..... do.....	22	9	25	16	22	18	23	18
Calves weaned..... do.....	19	9	23	14	21	18	22	18
Cows producing calves..... percent.....	88	39.1	100	66.7	91.7	78.3	92	81.8
Calf crop weaned..... do.....	70	39.1	92	58.3	87.5	78.3	88	81.8
Average age of calves when weaned..... days.....	284	294	295	300	296	302	274	298
Average birth weight of calves..... pounds.....	69.2	65	66	61.0	68.5	65.4	65.5	66.9
Average weaning weight of calves..... do.....	421.3	429.4	453.9	503.2	512.6	501.1	460	503.3
Weight of weaned calf per cow..... do.....	320.2	168	447	293.5	448.5	392.2	404.8	411.8
Average weights of cows when calves were weaned..... do.....	701.1	831.7	578.3	855.4	864	889.2	858.6	883.9
Average gain or loss in weight of cows during lactation..... do.....	-167.3	-50.5	-84.1	+16.8	-105.8	-27.2	-101.0	-36.1
Cows calving 2 consecutive years..... percent.....	30.4	5	58.3	10	78.3	9	81.8	12
Yearling heifers (1939 calf crop)..... number.....	459	3	829	10	825	9	524	12
Average weight at 12 months..... pounds.....	591	591	700	700	711	711	740	740
Total weaning weights of calves in 2 years..... do.....	11,865	11,865	18,210	18,210	19,790	19,790	19,220	19,220
Average weaning weight of calves in 2 years..... do.....	423.9	423.9	492.4	492.4	507.3	507.3	479.5	479.5
Appraised value of weaned calves per hundredweight..... dollars.....	7.00	7.00	8.00	8.00	8.00	8.00	8.00	8.00
Total value of weaned calves in 2 years..... do.....	\$20.55	\$20.55	1,456.80	1,456.80	1,583.20	1,583.20	1,537.60	1,537.60
Average value of weaned calf..... do.....	28.67	28.67	39.39	39.39	40.58	40.58	38.36	38.36
Total supplement fed to cows..... pounds.....	0	0	5,643	5,643	5,686	5,686	3,616	3,616
Cost of supplement per group..... dollars.....	0	0	141.08	141.08	169.98	169.98	131.87	131.87
Cost of supplement ² per weaning calf produced..... do.....	0	0	3.81	3.81	4.36	4.36	3.50	3.50
Net increased return per calf due to Supplement..... do.....	0	0	5.91	5.91	6.55	6.55	4.89	4.89
Average value of calf less cost of supplement..... do.....	29.67	29.67	35.58	35.58	36.22	36.22	34.86	34.86

¹ Applies only to the heifers retained in the project.² Total cost of supplement fed to the cows in each group was charged to the number of calves weaned in that group.

Table 2 shows no advantage in weight of cows or calves from the inclusion of calcium, iron, manganese, copper, cobalt, boron, or zinc with a phosphorus supplement. Group 3, which received disodium phosphate, produced slightly more pounds of beef as measured by weights of calves weaned than did either group 2, which received in bonemeal both calcium and phosphorus, or group 4, which received calcium and the so-called trace minerals in addition to phosphorus. The increased amounts of supplement fed to groups 2 and 3 during lactation were not justified as there were no significant advantages either in condition or fertility of these cows over the lactating cows of group 4, which were kept at the 6.5-gm. level, nor were the calves of groups 2 and 3 significantly heavier when weaned ($p > 0.05$). The differences between weaning weights of calves in groups 1 and 3 were highly significant. Differences between calves in groups 1 and 2 were significant. Differences in weaning weights between any two groups of calves from supplement-fed cows were not significant. An average difference of 55.6 pounds per calf between groups 1 and 4, although below statistical significance, is of material importance to the producer of calves. When weaning weights were corrected for age, differences between the calves in group 1 and the average for those in groups 2, 3, and 4 were highly significant. No significant differences in birth weight of calves resulted from supplemental feeding.

In calf-crop percentage, the difference between groups 1 and 4 was highly significant and between groups 2 and 3 the difference was sig-



FIGURE 9. Cow at left received phosphorus supplement and the one at right none. Note the more thrifty condition of both cow and calf at left. Photograph taken at end of 2½ years of the experiment.

significant. For the 2 years the calf crop for the control cows averaged about 64 percent and for the cows fed supplemental minerals about 85 percent.

At 12 months of age the supplement-fed heifers in groups 2, 3, and 4 averaged 69 pounds per head greater than the controls. This difference was highly significant. When the animals had reached 18 months of age, the difference had increased to 126 pounds, which was likewise highly significant (figs. 10 and 11).



FIGURE 10. These yearling heifers, as well as their dams, were fed no phosphorus supplement. Photograph taken in June 1940.

Of the seven cows in group 1 that were in the best condition at the conclusion of the 1939 lactation period, six raised calves during the 2 years (1939 and 1940). Their calves, however, were below the average in weaning weight. The fact that estrus does not regularly occur in cows severely affected with aphosphorosis allows them to recover much of the phosphorus drained from their skeletons between pregnancies. In 1939 eight of the lactating cows of group 1 had advanced cases of creeps and four others of the group were on the verge of this disease when their calves were weaned. One cow died as a result of this malady and several calves were weaned younger than they normally would have been in order to save their dams. The presence of creeps was diagnosed in three of the nine cows in this group that produced calves in 1940. Practically all cows of group 1 were observed chewing bones at some time during the test, whereas no



FIGURE 11.—These yearling heifers were fed disodium phosphate after weaning. Their dams likewise were fed disodium phosphate. Photograph taken in June 1940.

evidences of depraved appetite were observed among the cows of the other groups. All groups fed phosphorus supplement had noticeably better health, vigor, and thrift than the control group.

The relationship between the results obtained and the amount and cost of supplements fed is given in table 2. Owing to their superior condition, the calves from the cows fed phosphorus supplement were appraised at 1 cent per pound more at weaning than those from the control cows. The higher value per pound, together with the greater weights and numbers of the calves, much more than offset the cost of the supplements fed their dams. The supplement-fed groups produced, on the average for the 2-year period, 7,208 pounds, or 60 per cent, more beef than the controls, as measured by weights of calves at weaning time. The average value of the weaned calves from the supplement-fed cows, less the cost of the supplement, was \$5.78 more per head than that of the control calves.

BLOOD-CHEMISTRY STUDIES

INORGANIC PHOSPHORUS

The average amounts of inorganic phosphorus in blood samples collected from the various classes of experimental cattle are given in table 3.

Of the samples collected from the control group, only 9 had a phosphorus content of 4.0 mg. or more per 100 cc. of blood, whereas of those from groups 2, 3, and 4, only 1, 2, and 12, respectively, had less than that amount.

The average monthly phosphorus content of the blood samples from each group of cows is shown in figure 12. The supplement-fed groups paralleled one another rather closely, but the blood from the group fed bonemeal and trace minerals had a somewhat lower average than the other two from May 1939 to almost the close of the experiment. The phosphorus level of the blood from the cows in group 4 averaged less than 4.0 mg. 6 times during the experiment, whereas the blood of the other two mineral-fed groups was above this level except for 1 instance for the group fed bonemeal. The monthly average of the blood from the control cows was never above 4.0 mg. Many samples collected from lactating cows in this group had less than 2.5 mg. of phosphorus per 100 cc., whereas the blood of the lactating cows of groups 2, 3, and 4 remained practically the same as that of the dry cows of those groups except for an occasional slight deficiency among the lactating cows of group 4. It was always possible to diagnose aphosphorosis among the cows of group 1 by blood analysis before actual physical symptoms of this condition appeared.

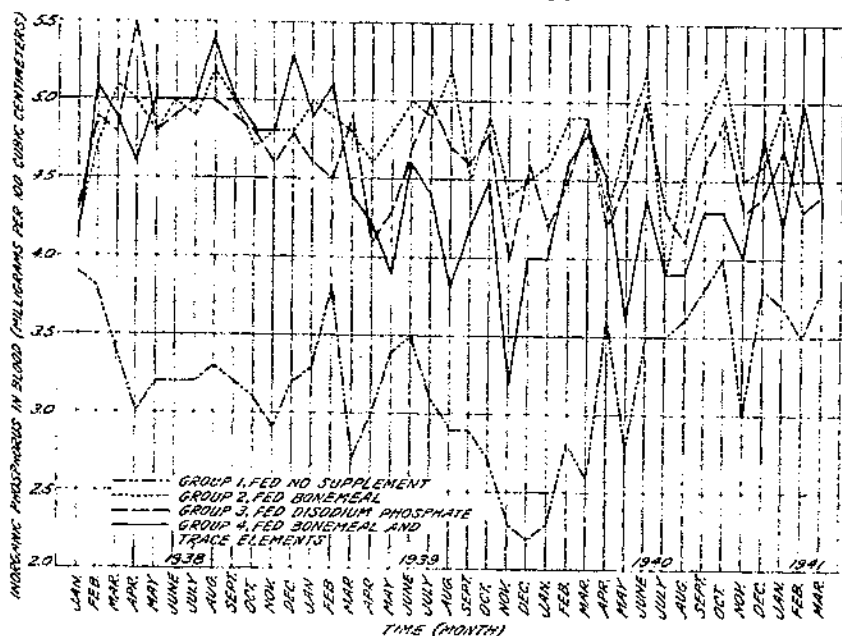


FIGURE 12.—Inorganic phosphorus in blood samples taken from cows at regular intervals during the experiment.

TABLE 3.—Average amounts of inorganic phosphorus in blood samples taken in 1939 and 1940 from cows and their offspring

Item	Group 1		Group 2		Group 3		Group 4	
	1939	1940	1939	1940	1939	1940	1939	1940
Lactating cows.....number.....	19	9	23	14	21	18	22	18
Blood samples from—								
Cows.....do.....	73	35	93	56	86	73	92	77
Calves.....do.....	83	35	103	56	102	70	99	69
Yearling heifers retained for breeding.....do.....		62		63		64		70
Average phosphorus content per 100 cc. of blood in—								
Cows.....milligrams.....	2.4	3.2	3.8	4.8	4.6	4.5	4.1	4.0
Calves.....do.....	6.3	6.6	6.7	6.7	6.4	6.8	6.7	6.3
Yearling heifers.....do.....		4.2		5.5		5.3		5.4

The average phosphorus content of the blood samples from the calves and yearling heifers in each group by months is shown graphically in figure 13. From May to December 1939, the general trend was a decrease in phosphorus in the blood of all groups of calves. Although group 1 had the greatest reduction, differences among all the groups were not important. From December 1939 to the end of the experiment there were sharp increases and decreases but the general trend was downward, and there continued to be no appreciable differences among the supplement-fed groups after weaning and during the year-

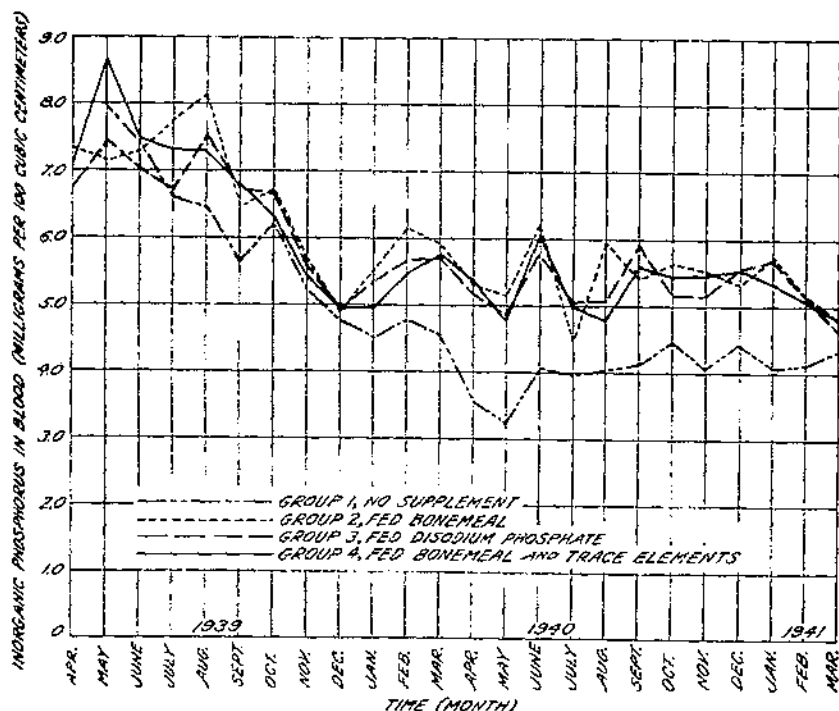


FIGURE 13.—Inorganic phosphorus in blood samples taken from offspring (8 months to 2 years of age).

TABLE 4.—Average hemoglobin content in blood (grams per 100 cc.) from cows, calves, and yearlings

Class of cattle	Period	Group 1 (controls), fed no supplement in—				Group 2, fed bonemeal in—				Group 3, fed disodium phosphate in—				Group 4, fed bonemeal and trace minerals in—			
		1938	1939	1940	1941	1938	1939	1940	1941	1938	1939	1940	1941	1938	1939	1940	1941
Cows	Jan.-Mar.		11.37	10.32	11.96		11.92	11.12	11.60		11.19	10.91	11.52		11.47	11.33	11.34
	Apr.-June		10.66	10.74			10.61	10.29			11.17	10.95			11.30	11.01	
	July-Aug.		10.48	11.78			10.40	11.53			10.80	11.64			10.38	11.48	
	Sept.-Dec.	10.90	11.13	12.06		11.25	11.40	11.63		11.54	11.85	11.35		12.93	11.43	11.29	
	Average	10.90	10.91	11.22	11.96	11.25	11.09	11.13	11.60	11.51	11.36	11.21	11.52	12.93	11.39	11.28	11.34
Calves	Jan.-Mar.		9.89	11.19	11.40		10.41	13.06	11.27		10.69	10.35	11.99		11.30	9.13	12.31
	Apr.-June		9.11	11.09			10.72	10.49			9.61	11.14			9.89	10.90	
	July-Sept.		10.13	10.80			11.17	12.47			10.79	11.51			11.91	11.83	
	Oct.-Dec.		11.75	11.08			11.83	11.45			11.74	11.54			12.05	11.93	
	Average		10.22	11.04	11.40		11.03	11.87	11.27		10.71	11.14	11.99		11.29	10.95	12.31
Yearlings	Jan.-Mar.			11.49				10.97				11.59				12.40	
	Apr.-June			10.71				10.99				10.76				10.96	
	July-Sept.			10.77				10.70				11.74				10.64	
	Oct.-Dec.			11.35				10.44				11.35				11.47	
	Average			11.08				10.78				11.36				11.37	

ling stage. All these groups were considerably above the 4-mg. level, the point where phosphorus deficiency may exist. The lowest level for the yearlings fed phosphorus supplements was 4.4 mg. in July 1940 for group 2, fed bone meal. At the end of the experiment all three of these groups had essentially the same phosphorus level (4.66 and 4.8 mg.). The controls as yearlings had a low level of 3.22 mg. in May and an average of 4.2, which indicated they were on the danger line so far as phosphorus deficiency was concerned.

HEMOGLOBIN DETERMINATIONS

There were no consistent differences in the amount of hemoglobin in the blood of the various cattle, as shown in table 4. The three groups of supplement-fed cows, however, had a somewhat higher content in 1938 and 1939 than the control group but practically the same content during the remainder of the test. In 1939 calves from the control group had a somewhat lower hemoglobin content than those from the supplement-fed groups, but in the 2 succeeding years differences were inconsistent.

As yearlings, the calves born in 1939 in the various groups showed no material differences in hemoglobin in their blood. At the end of 3 years there was also no difference, indicating no relationship between hemoglobin content and phosphorus intake. The trace minerals—iron, copper, manganese, zinc, boron, and cobalt—fed in addition to phosphorus to group 4 seemingly had no effect on the hemoglobin content of the blood.

SUMMARY AND CONCLUSIONS

The investigations reported in this bulletin were made from 1937 to 1941 inclusive to determine what mineral elements were deficient in the vegetation of southern Texas and the methods of correcting such deficiencies. The work was conducted in cooperation with the Texas Agricultural Experiment Station and the King Ranch, at Kingsville, Tex. The vegetation of the area consisted primarily of species of *Andropogon* (sage grasses and bluestem), *Paspalum* (Georgia or honeydew grass), *Sporobolus* (smutgrass), *Panicum*, *Elyonurus tripsacoides* (joint grass), and *Aristida* (three-awn).

Comparatively few samples of vegetation contained more than 0.13 percent of phosphorus, but most of them contained more than 0.23 percent of calcium. The indication, therefore, is that cattle grazing such forage would not get sufficient phosphorus to meet their requirements, but that the calcium would be ample. A low protein content of the forage was usually found to be associated with a low phosphorus content. Considerable differences existed in the composition of different species and in the same species in different localities and on different soils. The effect of rainfall was usually reflected in increased percentages of phosphorus in the months following the heaviest precipitation.

In tests involving the feeding of mineral supplements, 100 Brahman×Shorthorn and Brahman×Hereford heifers about 18 months of age were used. These heifers were divided into 4 groups but used the same range and watering facilities. Five Santa Gertrudis bulls were allotted to these heifers and allowed to remain with them throughout the experiment—from January 1938 to March 1941.

The control cattle (group 1) received no mineral supplement. The three remaining groups were hand-dosed, six times a week, with the following mineral supplements: Group 2, bonemeal; group 3, disodium phosphate; and group 4, bonemeal with small quantities of iron, manganese, copper, cobalt, zinc, and boron. In groups 2 and 3, bonemeal and disodium phosphate were fed in such quantities as to supply 6.5 gm. of phosphorus to dry cows and 14.3 gm. to lactating cows, per head daily. Group 4 cows, whether dry or in lactation, were kept at the 6.5-gm. level. Blood samples were taken from representative cows and calves in each group for inorganic phosphorus and hemoglobin determinations. All suitable heifer calves produced in each group were retained and after weaning were fed the same mineral supplements as their respective dams.

Except for several months at the beginning and end of the experiment, the average weights of the cows in each of the mineral-fed groups were significantly higher than those of the control cows. The comparatively high weights of the controls at the end of the experiment were due to the fact that there were considerably more dry cows in this group as the experiment progressed, and that they tend to fatten more readily than pregnant or lactating cows. Differences between the supplement-fed groups were not significant at any time during the experiment.

The primary advantage in feeding a phosphorus supplement to cows under the conditions of this experiment is the increased percentage of the calf crops and greater weights attained by the offspring. Based on a 2-year average, only 64 percent of the control cows produced calves as compared with 85 percent for those supplement fed. This difference was highly significant. Differences between the supplement-fed groups were not significant. For the 2-year period also, the control cows weaned only 58 percent of their calves, whereas the supplement-fed cows weaned 81 percent. Only slightly more than 30 percent of the control cows calved in 2 consecutive years, whereas the supplement-fed cows averaged about 73 percent. The difference was highly significant.

The feeding of phosphorus supplements to cows had no influence on the birth weights of calves. However, on the average for 2 years, the weaning weight per calf in the supplement-fed group was 69 pounds more than in the control group, which was a considerable advantage. Furthermore, the calves from the supplement-fed cows were appraised at 1 cent per pound more than those from the control cows. The average value of the former calves at weaning, less the cost of the supplement, was \$35.45 per head, which was \$5.78 more than the value per head of the control calves.

Differences in weaning weights of the calves in the supplement-fed groups were not statistically significant. At 12 months of age the difference in average weight between the heifers in the supplement-fed and control groups was essentially the same as at weaning time, but at 18 months of age the former heifers averaged 126 pounds heavier than the latter.

The increased quantities of phosphorus fed to lactating cows in groups 2 and 3 and the additional trace minerals fed to the cows in group 4 resulted in no additional benefits as measured by weights of cows during lactation or by gains in weight of calves nursing the cows.

Aphosphorosis could be diagnosed from the inorganic phosphorus determinations of the blood even before actual physical symptoms of this condition became apparent. The monthly average phosphorus in the blood samples from the control cows was always less than 4 mg. per 100 cc. of blood, the point at which phosphorus deficiency may exist. In only a few instances were the blood samples of the supplement-fed cows below this level. Practically all control cows were observed chewing bones at some period during the course of the test, but there was no evidence of this among the supplement-fed cows.

There were no consistent differences in the hemoglobin content of the blood samples taken from the various groups of cattle, indicating no close relationship between phosphorus intake and hemoglobin in the blood. Likewise, iron and other trace minerals had no effect on the hemoglobin content of the blood.

The study showed, therefore, a definite phosphorus deficiency in southern Texas and yielded the following information on correcting this deficiency: The feeding of supplements that supplied 6.5 gm. of phosphorus 6 days per week to dry cattle grazing phosphorus-deficient vegetation prevented aphosphorosis and corrected already existing phosphorus deficiencies if they were not too far advanced. In lactating cows 14.3 gm. of phosphorus daily resulted in a somewhat higher phosphorus content of the blood than 6.5 gm. Although the latter group had a slight deficiency at times, the condition was not serious. Disodium phosphate and bonemeal, when fed to range cattle so as to supply the same quantity of phosphorus, were of similar relative values as supplements to phosphorus-deficient vegetation.

LITERATURE CITED

- (1) BEKKER, J. G.
1922. STUDIES ON MINERAL METABOLISM. XXIV. "ON THE ADMINISTRATION OF PHOSPHORUS TO ANIMALS THROUGH THEIR WATER SUPPLY." Union So. Africa Dept. Agr. Rpt. Dir. Vet. Serv. and Anim. Indus. 18: 751-797, illus.
- (2) DU TOIT, P. J., and BISSCHOP, J. H. R.
1929. THE BREEDING OF CATTLE ON PHOSPHORUS DEFICIENT VELD. Union So. Africa Dept. Agr. Rpt. Dir. Vet. Serv. and Anim. Indus. 15: 1050-1166, illus.
- (3) FRAPS, G. S., and FUDGE, J. F.
1940. THE CHEMICAL COMPOSITION OF FORAGE GRASSES OF THE EAST TEXAS TIMBER COUNTRY. Tex. Agr. Expt. Sta. Bul. 582, 35 pp.
- (4) MALAN, A. I., GREEN, H. H., and DU TOIT, P. J.
1928. STUDIES IN MINERAL METABOLISM. V. COMPOSITION OF BOVINE BLOOD ON PHOSPHORUS DEFICIENT PASTURES. Jour. Agri. Sci. (England) 18: (376)-383.
- (5) ——— and VAN DER LINGEN, G. W. B.
1931. STUDIES IN MINERAL METABOLISM. XVI. THE MICRO-DETERMINATION OF SOME INORGANIC ELEMENTS IN BLOOD AND VEGETATION. Union So. Africa Dept. Agr. Rpt. Dir. Vet. Serv. and Anim. Indus. 17: 443-452.
- (6) SCHMIDT, H.
1926. FEEDING BONE MEAL TO RANGE CATTLE ON THE COASTAL PLAINS OF TEXAS. PRELIMINARY REPORT. Tex. Agr. Expt. Sta. Bul. 344, 37 pp., illus.
- (7) SNEDECOR, G. W.
1940. STATISTICAL METHODS APPLIED TO EXPERIMENTS IN AGRICULTURE AND BIOLOGY. Ed. 3, 422 pp., illus. Ames, Iowa.
- (8) THEILER, A., GREEN, H. H., and DU TOIT, P. J.
1924. PHOSPHORUS IN THE LIVESTOCK INDUSTRY. Union So. Africa Dept. Agri. Jour. 8: 460-504, illus.
- (9) ——— GREEN, H. H., and DU TOIT, P. J.
1927. MINIMUM MINERAL REQUIREMENTS IN CATTLE. Jour. Agri. Sci. (England) 17: (291)-314, illus.

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