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Methods of Supplying Phosphorus to Range Cattle in South Texas

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DIGEST

Extensive areas of sandy soils in South Texas are low in phosphorus. Experiments conducted from 1937 to 1941 showed that the vegetation on these soils was low in phosphorus and that range cattle, especially lactating cows, frequently showed symptoms of phosphorus deficiency. Hand-feeding of phosphorus supplements — bonemeal and disodium phosphate — prevented phosphorus deficiency and corrected already existing deficiencies if they were not too far advanced.

Additional work was conducted from 1941 to 1946 to develop more practical methods of supplying phosphorus to cattle, and to determine the effect of applications of different phosphates on the yield and chemical composition of pasture forage. The work was conducted on Nueces fine sand, a typical phosphorus-deficient soil of the region, on the King ranch near Falfurrias.

Phosphorus was supplied to the cattle by feeding bonemeal in self-feeders, by adding disodium phosphate to the water supply and by fertilizing pastures with triple superphosphate. All three methods of supplying phosphorus prevented phosphorus deficiency in cattle in normal seasons. Fertilized pasture had a greater carrying capacity than unfertilized pasture. During prolonged drouth, however, the fertilized pasture did not supply enough forage and phosphorus for the cattle at the heavy rate of stocking used.

Cows that received phosphorus supplements and cows on pasture fertilized with triple superphosphate produced larger calf crops and heavier calves at weaning time than cows that did not receive phosphorus supplements.

The cows that did not receive a phosphorus supplement produced 93 pounds of weaned calves per acre; cows that were fed bonemeal, 116 pounds; cows that received disodium phosphate in drinking water, 143 pounds; and cows on fertilized pasture, 176 pounds.

The group of cows that did not receive a phosphorus supplement yielded a gross return of $13.91 per acre for the 4 years. After deducting the cost of phosphorus supplements or fertilizer, the cows that were fed bonemeal gave a return of $16.91 per acre; cows that received disodium phosphate in water, $20.39; and cows on fertilized pasture, $19.97.

Feeding phosphorus supplements increased the amount of inorganic phosphorus in the blood stream of the cattle.

Applications of several different phosphates to pastures increased the yield and phosphorus content of pasture forage, but had little effect on its protein content.

The front cover picture is of the first cross Brahman-Hereford heifers at the start of the experiment, July 30, 1941.

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THE RESULTS PUBLISHED in this bulletin were obtained in an experiment on methods of supplying phosphorus to range cattle conducted jointly by the King ranch, the Texas Agricultural Experiment Station and the Bureau of Animal Industry of the United States Department of Agriculture near Falfurrias from 1941 to 1946. The Tennessee Valley Authority, Knoxville, Tennessee, furnished the phosphates used in pasture fertilization.

The work consisted of two phases: (1) application of phosphates to range land to determine the effects of phosphate on yield and chemical composition of forage; and (2) supplying phosphorus to range cattle in a controlled water supply, feeding phosphorus supplements in self-feeders and grazing cattle on pasture fertilized with triple superphosphate. Some of the results of the work to determine the effects of phosphate on yield and chemical composition of range forage were reported in 1951 in Texas Station P. R. 1341, "Supplying Phosphorus to Range Cattle Through Fertilization of Range Land," by E. B. Reynolds, J. F. Fudge and J. M. Jones. The results obtained on methods of supplying phosphorus to range cattle were published in 1949 in USDA Technical Bulletin 981, "Comparison of Methods of Supplying Phosphorus to Range Cattle," by W. H. Black, L. H. Tash, J. M. Jones and R. J. Kleberg, Jr.

The results of both phases of the experiment are brought together in revised form in this bulletin so they will be available to Texas ranchmen in one publication.

REVIEW OF LITERATURE

Much research has been done on feeding phosphorus supplements to cattle on phosphorus-deficient soils in various parts of the world during the last 25 years. A complete review of the literature on the subject is not necesarry in this bulletin. A brief survey of the research in Texas bearing on phosphorus deficiency is given here.

It has been known for many years that the soils in the Gulf Coast Prairie of Texas are deficient in phosphorus. It was surmised that certain diseases of cattle might be connected in some way with low phosphorus content of the soils in the region (6). Schmidt (7) reported in 1926 that feeding mixtures of bonemeal and salt to range cattle in the region prevented "creeps" (an extreme deficiency of phosphorus, which is also called aphosphorosis) and greatly reduced losses from diseases other than those of an infectious character. Cows that were fed bonemeal reared more and better calves than cows that were not fed bonemeal.

Stansel, Reynolds and Jones (8), in conducting pasture investigations at the Angleton station in Brazoria county, stated that mature grasses did not contain enough phosphorus for adequate nutrition of range cattle. When harvested at monthly intervals, however, the regrowth of Dallis, Bermuda and Angleton grasses contained enough phosphorus.

Fraps, Fudge and Reynolds (4) found that the application of superphosphate to pastures greatly increased the yield and phosphorus content of total pasture forage and of carpet grass. In general, application of superphosphate provided enough phosphorus in the forage for range cattle.

Reynolds and Wyche (5) reported that fertilizers containing superphosphate more than doubled the yield of forage and increased its phosphoric acid content about 50 percent and its protein content about 20 percent on a heavy black clay soil at Beaumont in the Gulf Coast Prairie from 1936 to 1943.

Fraps and Fudge (2) showed that many soils in Texas are low in phosphorus. They also found a high correlation between the phosphorus content of grasses and the total phosphorus content of the soils in East Texas (3).

Black, Tash, Jones and Kleberg (1) made an extensive study from 1937 to 1941 to determine what mineral elements were deficient in the vegetation of South Texas and methods of correcting such deficiencies. Previous work in South Africa had shown that feeding adequate amounts of bonemeal would prevent phosphorus deficiency in cattle. Feeding bonemeal brought about a remarkable improvement in growth and condition of the cattle. Bonemeal increased the fertility and milk flow, and these in turn produced more and larger calves.

It was thought that the results of studies on phosphorus in South Africa might be applicable

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to large areas in South Texas where the soils also are low in phosphorus (2). For this reason, work was started in 1937 to determine the extent of mineral deficiencies, especially phosphorus deficiency, in the vegetation of the region. The work consisted of three main phases: (a) the collection and chemical analysis of samples of the vegetation; (b) the feeding of bonemeal and other phosphorus supplements to range cattle; and (c) the collection and analysis of blood samples from cattle for inorganic phosphorus.

Black, Tash, Jones and Kleberg (1) reported that comparatively few of the vegetation samples 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 on such forage would not get sufficient phosphorus to meet their requirements, but that calcium would be ample. The protein and phosphorus contents of most of the species analyzed tended to be the lowest during winter and drouth periods, when there was the least green feed. Considerable differences existed in the composition of different species and in the same species in various localities and on different soils. The effect of rainfall was usually reflected in increased percentages of phosphorus in the months following the heaviest precipitation.

These workers found that feeding supplements which supplied as much as 6.5 grams of phosphorus 6 days per week to dry cows grazing phosphorus-deficient vegetation prevented phosphorus deficiency (Figure 1). Phosphorus supplements increased the number of calves and the weight of both cows and calves. In lactating cows, the feeding of 13.4 grams of phosphorus daily resulted in somewhat higher phosphorus content of the blood than 6.5 grams. Disodium phosphate and bonemeal had about the same value as supplements for cattle pastured on phosphorus-deficient vegetation.

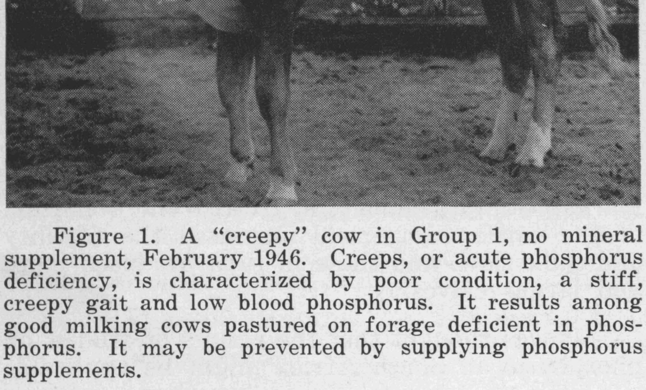

Figure 1. A "creepy" cow in Group 1, no mineral supplement, February 1946. Creeps, or acute phosphorus deficiency, is characterized by poor condition, a stiff, creepy gait and low blood phosphorus. It results among good milking cows pastured on forage deficient in phosphorus. It may be prevented by supplying phosphorus supplements.

OBJECT OF THE WORK

In view of the results obtained by Black, Tash, Jones and Kleberg (1), additional work was done to compare different methods of supplying phosphorus to range cattle and to determine the effect of applications of phosphates on the chemical composition of range forage. The specific objectives of the work were: (a) to determine the most practical methods of supplying phosphorus to range cattle; and (b) to determine the effect of the application of phosphates on the phosphorus and protein content of range grasses and on the production of calves.

Accordingly, the work at the King ranch was revised and expanded to attain these objectives. The revised work included the feeding of bonemeal in self-feeders, the addition of disodium phosphate to the water supply and the large-scale application of phosphates to range land. The work also included various rates of application of different phosphates on small plots to determine their effect on the yield and chemical composition of range forage.

VEGETATION, SOILS AND RAINFALL OF THE REGION

The southern part of Texas, in which this work on phosphorus was conducted, has a generally smooth undulating surface. It supports a growth of varying density of grasses, brush, shrubs and some scattered trees.

Vegetation

That part of the area where this work was conducted was formerly a tall bunch-type grassland broken only by small areas of live oak brush. Major grasses were seacoast blustem (*Andropogon littoralis*), brownseed paspalum (*Paspalum plicatulum*), hairy grama (*Bouteloua hirsuta*), thinleaf paspalum (*Paspalum setaceum*), switchgrass (*Panicum virgatum*), fringeleaf paspalum (*Paspalum ciliatifolium*), sandhill grass (*Brachiaria ciliatissima*) and gulf cordgrass (*Spartina spartinae*). The important forbs included indigo (*Indigofera miniata*), milk pea (*Galactia texana*) and partridge pea (*Cassia fasciculata*).

The present vegetation is a mesquite grassland savannah, consisting of scattered to dense stands of mesquite (*Prosopis chilensis*) as an overstory to the grasses and forbs. Major grasses are sandhill grass, three-awn grasses (*Aristida spp.*), gulf cordgrass, with only remnants of the taller bunch-type grasses, which formerly were prevalent in the area, remaining in the more favorable situations. The important forbs include sunflower (*Helianthus spp.*), croton (*Cro-*

ton spp.) and local stands of milk pea and partridge pea.

Present forage production generally is highly seasonal, the major portions of which usually come in the spring and fall as a direct result of the seasonal rainfall. The grasses deteriorate rapidly following maturity and, when dried, the quality and quantity of the forage is appreciably reduced. Lactating cows on range not supplemented with phosphorus become deficient in phosphorus.

Soils

The soils range from dark, heavy, deep, productive clays and clay loams on the more level areas to brown soils of medium depth, very shallow loamy soils and light-colored, deep, loose sandy soils of low productivity on the undulating surfaces.

The experiment was conducted on Nueces fine sand, a loose sand subject to wind erosion, on the Encino division of the King ranch in Brooks county near Falfurrias. Nueces fine sand is an extensive soil in Brooks, Kenedy, Jim Wells and Hidalgo counties. This soil is low in organic matter and plant nutrients, especially phosphorus. Previous work (1) has shown that grasses growing on this soil are low in phosphorus.

Rainfall

The climate of the area is mild, and that of the southern part is subtropical and subhumid. The average yearly rainfall is about 30 inches in the eastern part and gradually decreases westward to approximately 20 inches or less in the extreme western part. The region is subject to frequent drouths.

Data on rainfall at the Encino division of the King ranch during 1941-48 are given in Table 1. The record of monthly rainfall for 1947 was lost, but the total for the year was 31 inches. The average yearly rainfall for the period was 25.58 inches, which was 1.43 inches greater than the 41-year average of 24.15 inches. The rainfall, however, varied widely from year to year and from month to month. It ranged from 34.34 inches in 1941 to 16.17 inches in 1945. September had the highest average rainfall, 5.44 inches, for the 7 years and 3.95 inches for 41 years. November, December and February had the lowest average rainfall for the 7 years, but January, February and March had the lowest average for the 41 years.

The amount and distribution of rainfall greatly influenced the yield and chemical composition of pasture forage.

METHOD OF CONDUCTING THE WORK

The work on supplying phosphorus to range cattle was conducted from 1941 to 1946 on the Encino division, about 25 miles south of Falfurrias and 60 miles southwest of Kingsville. Although that part of the experiment involving cattle was completed in November 1946, the plot work with phosphates to obtain yields of forage was continued through 1948.

This experiment included application of phosphates on small plots to determine the effects of phosphates on yield and chemical composition of forage, supplying phosphorus in a controlled water supply, feeding phosphorus supplements in self-feeders and grazing cattle on pasture fertilized with triple superphosphate.

The cattle, pastures, corrals, scales and labor were furnished by the King ranch. The Tennessee Valley Authority furnished the triple superphosphate used for pasture fertilization. The Texas Agricultural Experiment Station and the Bureau of Animal Industry supervised the project and were responsible for the technical phases of the work and the collection of data.

Application of Phosphates on Small Plots

Triple superphosphate (about 48 percent), calcium metaphosphate and potassium metaphos-

Table 1. Monthly and yearly rainfall in inches on the Encino division of the King ranch, 1941-48[1]

Month	1941	1942	1943	1944	1945	1946	1948	7-year average	41-year average[2]
January	2.25	1.85	5.25	0.98	1.08	2.03	0.60	2.01	1.20
February	1.68	1.98	0.21	0.22	0.60	0.00	3.00	1.10	0.91
March	5.32	0.17	1.18	5.00	2.14	0.31	1.50	2.23	1.09
April	4.72	0.48	0.17	0.93	2.05	0.89	1.16	1.49	1.92
May	4.00	1.98	4.03	2.57	1.29	0.46	1.86	2.31	2.98
June	5.20	2.64	1.23	1.08	0.61	3.82	1.26	2.26	2.92
July	2.65	2.26	0.24	1.20	0.37	0.40	2.85	1.42	2.04
August	0.00	0.63	0.78	7.62	1.91	1.44	1.84	2.03	2.04
September	2.00	1.40	5.90	4.36	2.10	7.75	14.56	5.44	3.95
October	4.02	4.99	1.22	0.96	4.08	2.48	4.43	3.17	2.05
November	0.45	0.52	3.13	0.60	0.00	0.00	0.00	0.67	1.40
December	2.05	0.09	1.46	0.58	0.54	0.00	0.00	0.67	1.65
Total	34.34	18.99	24.80	26.10	16.77	19.58	33.06	25.58[3]	24.15

[1]Records of monthly rainfall for 1947 were lost, but the total rainfall for that year was 31.00 inches.
[2]At Falfurrias, about 25 miles from the experimental area, as reported by the U.S. Weather Bureau.
[3]This average of 25.58 inches is for 8 years, 1941-48.

phate were applied on small plots in the spring of 1941; applications were not repeated in subsequent years. The triple superphosphate was applied at rates of 100, 200, 400 and 800 pounds per acre. The calcium and potassium metaphosphates were used at rates of 162 and 164 pounds per acre, which supplied the same amount of phosphorus as 200 pounds of triple superphosphate. These treatments were laid down on plots 50 feet wide and 300 feet long and were replicated three times. All of the phosphates were applied on the surface of the soil with a fertilizer drill.

Additional plots were established in June 1943 on which fused tricalcium phosphate, a new phosphatic material, was compared with triple superphosphate. On these plots, the triple superphosphate was used at rates of 100, 200 and 400 pounds per acre. The fused phosphate was applied at rates of 178, 356 and 712 pounds per acre, which supplied the same amounts of phosphorus as 100, 200 and 400 pounds of triple superphosphate, respectively.

The plots were not grazed during the period of the experiment. Yields of forage were obtained on all of the plots. Chemical analyses were made to determine the phosphorus and protein contents of the two main species of grasses, *Paspalum plicatulum* and *Paspalum setaceum*.

Methods of Supplying Phosphorus to Cattle

This part of the experiment was conducted with four groups of cows of Brahman-Hereford breeding. At the outset, 184 heifers, about 20 months old, were divided at random and placed in different pastures. Pasture 1 contained 575 acres; pasture 2, 681 acres; pasture 3, 586 acres; and pasture 4, 684 acres. Groups 1, 2 and 3 averaged 42 head per year and group 4, 58 head. These cattle were handled as follows:

Group 1, pasture 1, no mineral supplement.

Group 2, pasture 2, had access to bonemeal in self-feeders.

Group 3, pasture 3, received disodium phosphate in water. From 20 to 27.5 pounds of disodium phosphate, containing 8.74 percent of phosphorus, were added to 1,000 gallons of water. This solution supplied slightly more than 1 gram of phosphorus per gallon.

Group 4, pasture 4, area was fertilized in July 1941 with 56.64 tons of 48 percent triple superphosphate. About 77 acres of brushy land could not be covered. The application approximated 90 pounds of phosphoric acid (P_2O_5) per acre on 607 acres.

Heifers averaging 706 pounds were placed on the pastures in July 1941 and were kept on them continuously until November 1946, when the experiment was discontinued. Pastures 1 and 3 were stocked at the rate of approximately 1 cow to 14 acres; pasture 2, 1 cow to 16 acres; and pasture 4, 1 cow to 12 acres. One Santa Gertrudis bull was used to 20 cows.

The individual weights of the cows were taken at monthly intervals from the beginning of the experiment through April 1945 and after that every 3 months. The weights of the cows at weaning time also were obtained after April 5, 1944. The weights of the calves were taken when they were weaned at approximately 240 days.

Blood samples were taken at 28-day intervals from 10 representative cows in each group to determine the comparative levels of blood phosphorus.

EXPERIMENTAL RESULTS

Yields of Forage

Yields of green forage obtained from the superphosphate plots established in 1941 for the 8 years, 1941-48, are given in Table 2. The yields varied greatly from year to year, depending on the amount and distribution of rainfall. The highest yields were obtained in 1941 and 1944, which were years of high rainfall (Table 1). Yields were not obtained in 1943. The low yields of forage in 1945 and 1946 indicated that the fertilized pasture did not provide enough forage and phosphorus for the 62 head of cattle ranging it. This also is reflected in the low blood phosphorus of the cows on the fertilized pasture in 1945 and 1946, as shown in Table 7.

All the plots treated with phosphates produced decidedly larger average yields of green forage than the unfertilized plots, Table 2. Plots that received potassium metaphosphate produced

Table 2. Yield per acre in pounds of green forage on fertilized plots, 1941-48[1]

Treatment per acre	1941[2]	1942[3]	1944[4]	1945[3]	1946[3]	1947[3]	1948[4]	Average	
								Pounds	Percent increase
800 lbs. superphosphate	10,620	1,330	5,240	2,790	1,440	2,140	2,180	3,680	41.0
400 lbs. superphosphate	10,610	1,710	5,410	3,310	1,470	2,790	2,760	4,010	53.6
200 lbs. superphosphate	9,080	1,860	4,690	2,280	1,260	2,810	2,790	3,540	35.6
100 lbs. superphosphate	9,170	1,870	4,600	2,270	1,280	2,990	2,150	3,480	33.3
164 lbs. potassium metaphosphate	10,710	1,800	5,290	2,570	1,530	3,450	2,980	4,050	55.2
162 lbs. calcium metaphosphate	9,070	2,120	5,100	2,790	1,150	2,910	2,930	3,730	42.9
None	6,930	1,120	3,190	1,220	1,040	3,060	1,720	2,610	
Average	9,460	1,690	4,790	2,460	1,310	2,880	2,500		

[1]Yields not obtained in 1943. [2]Total of 3 cuttings. [3]1 cutting. [4]Total of two cuttings.

Table 3. Yield per acre in pounds of green forage on fused phosphate plots, 1944-48

Treatment per acre	1944	1945	1946	1947	1948	Average	
						Pounds	Percent increase
712 lbs. fused phosphate	8,180	3,220	1,510	2,340	2,940	3,640	81.1
356 lbs. fused phosphate	7,510	2,370	1,290	2,440	3,060	3,330	65.7
178 lbs. fused phosphate	5,680	2,340	1,140	2,330	2,690	2,840	41.3
400 lbs. triple superphosphate	7,930	3,140	1,370	2,510	3,600	3,710	84.6
200 lbs. triple superphosphate	7,100	2,440	1,260	2,120	3,850	3,350	66.7
100 lbs. triple superphosphate	6,460	2,960	1,700	2,870	3,820	3,560	77.1
None	3,340	960	1,120	2,400	2,250	2,010	
Average	6,600	2,490	1,340	2,430	3,170		

a slightly higher average yield than any other treatment used. This possibly indicates that the potassium in potassium metaphosphate may have been responsible for part of the increase in yield. Plots treated with calcium metaphosphate produced a little larger yield than plots that received 200 pounds of triple superphosphate. The application of 400 pounds of triple superphosphate per acre was as effective as that of 800 pounds.

Fused tricalcium phosphate, a new phosphatic fertilizer, became available in 1943. A new series of plots was established that year to compare this material with triple superphosphate. The fused phosphate was applied at rates of 178, 356 and 712 pounds per acre, which supplied the same amounts of phosphorus as 100, 200 and 400 pounds of triple superphosphate, respectively. The yields of green forage obtained from these plots from 1944 through 1948 are given in Table 3. The treatment of 400 pounds of triple superphosphate made a slightly higher average yield than any other treatment. The phosphate treatments increased the average yields of forage 41.3 to 84.6 percent above the yield of the unfertilized plots. Triple superphosphate produced about 8 percent more forage than the fused phosphate. These results indicate that there was very little difference in the effectiveness of triple superphosphate and fused phosphate.

Phosphoric Acid Content of Grasses

The phosphoric acid content of the air-dry forage of the two main species of grasses, *Paspalum plicatulum* and *Paspalum setaceum*, was determined on samples collected when yields of forage were obtained. The phosphoric acid content of both grasses varied considerably from year to year. Apparently, the phosphoric acid content was associated with rainfall. It tended to be high in new growth and during periods of favorable rainfall, and low in winter and during periods of drouth.

As an average for the 7 years, the grasses on the plots that received phosphate contained from one and one-half to nearly three times as much phosphoric acid as the grasses from the plots which did not receive phosphorus, Table 4. In general, the phosphoric acid content of the grasses increased as the rate of application of triple superphosphate was increased. The heavier applications, 200, 400 and 800 pounds per acre, maintained the average phosphoric acid content at 0.33 percent or above, which usually is considered adequate for range cattle. According to this standard, the two grasses on the plots that received 400 or 800 pounds of triple superphosphate per acre contained enough phosphorus for range cattle at all dates of sampling, except

Table 4. Percentage of phosphoric acid (P_2O_5) in Paspalum plicatulum and Paspalum setaceum on fertilized plots, 1941-47

Treatment per acre	1941		1942		1943	1944		1945		1946		1947	Av.
	June 20	Sept. 5	July 27	Dec. 28	Oct. 22	June 22	Oct. 22	Sept. 20	Nov. 14	June 25	Oct. 3	Sept. 24	
Paspalum plicatulum													
800 lbs. triple superphosphate	0.83	0.38	0.67	0.50	[1]	0.71	0.54	0.52	0.43	0.51	0.58	0.40	0.55
400 lbs. triple superphosphate	.58	.30	.41	.32		.51	.39	.36	.35	.47	.46	.38	.41
200 lbs. triple superphosphate	.54	.30	.33	.37		.52	.25	.36	.18	.37	.46	.19	.35
100 lbs. triple superphosphate	.43	.23	.28	.28		.40	.28	.31	.24	.33	.38	.26	.31
164 lbs. potassium metaphosphate	.52	.29	.29	.25		.28	.20	.32	.17	.33	.39	.32	.31
162 lbs. calcium metaphosphate	.42	.24	.26	.20		.27	.25	.33	.23	.34	.42	.27	.28
None	.22	.19	.17	.13		.21	.17	.27	.18	.25	.29	.21	.21
Paspalum setaceum													
800 lbs. triple superphosphate	.83	[1]	.58	.74	.51	.74	.48	.63	.42	.73	.49	.53	.61
400 lbs. triple superphosphate	.58		.54	.54	.48	.58	.42	.47	.33	.55	.52	.44	.50
200 lbs. triple superphosphate	.54		.34	.40	.42	.43	.34	.43	.25	.46	.42	.43	.41
100 lbs. triple superphosphate	.43		.44	.40	.43	.36	.30	.36	.24	.33	.44	.31	.37
164 lbs. potassium metaphosphate	.61		.39	.38	.43	.29	.29	.36	.27	.38	.42	.41	.38
162 lbs. calcium metaphosphate	.47		.32	.37	.44	.32	.30	.36	.17	.33	.39	.31	.34
None	.27		.15	.25	.24	.16	.15	.23	.15	.21	.36	.21	.22

[1]Analysis of this species not obtained on this date.

September 5, 1941. The grasses from the unfertilized plots contained, on the average, only 0.21 percent of phosphoric acid.

Protein Content of Grasses

Apparently the application of different phosphates had no appreciable effect on the protein content of *Paspalum plicatulum* and *Paspalum setaceum*, as shown in Table 5. The protein content, however, varied widely in different seasons. It ranged from about 12 percent in September 1945 to 4 percent or below in October 1944. The protein content appeared to be associated with stage of growth and amount of rainfall. In general, a high protein content followed periods of favorable rainfall. There was not much difference in the average protein content of the two grasses.

Amount of Available Phosphoric Acid in the Soil

The amount of available phosphoric acid was determined in the soil on the areas involved in the work, including the small plots and the large fertilized and unfertilized pastures, in 1945 and 1947. The application of phosphates greatly increased the amount of available phosphoric acid in the soil, as shown in Table 6. For example, in 1945 the soil that received 800 pounds of triple superphosphate per acre contained 27 parts per million of available phosphoric acid (equal to 54 pounds per acre) in the surface soil, and the untreated soil contained 4 parts per million. In general, the amount of available phosphoric acid in the soil increased as the rate of application of phosphate was increased.

Soil treated with calcium and potassium metaphosphates contained about as much available phosphoric acid as soil treated with equal amounts of phosphoric acid in triple superphosphate.

Table 6. Amount of phosphoric acid (P_2O_5) in parts per million of surface soil at various places, 1945 and 1947

Treatment per acre	1945	1947
Superphosphate plots (established in 1941)		
800 lbs. triple superphosphate	27	21
400 lbs. triple superphosphate	14	6
200 lbs. triple superphosphate	11	4
100 lbs. triple superphosphate	7	5
164 lbs. potassium metaphosphate[1]	10	5
162 lbs. calcium metaphosphate[1]	10	4
None	4	3
Fused phosphate plots (established in 1943)		
400 lbs. triple superphosphate	16	7
200 lbs. triple superphosphate	9	4
100 lbs. triple superphosphate	6	4
712 lbs. fused phosphate[2]	25	15
356 lbs. fused phosphate[2]	19	8
178 lbs. fused phosphate[2]	6	4
None	5	3
Large pastures		
200 lbs. superphosphate, pasture 4	6	3
None—Pasture 1	4	3
Pasture 2		3
Pasture 3		2
200 lbs. triple superphosphate, Vivoras pasture		5
None, Vivoras pasture		4

[1]These amounts of potassium and calcium metaphosphate supply the same amounts of P_2O_5 as 200 pounds of triple superphosphate.

[2]The 178, 356 and 712 pounds of fused phosphate contain the same amounts of P_2O_5 as 100, 200 and 400 pounds of triple superphosphate, respectively.

Table 6 shows that the amount of available phosphoric acid in the fertilized soil was considerably less in 1947 than in 1945, which indicates that it was being depleted to the level of available phosphoric acid in the untreated soil.

Inorganic Phosphorus in Whole Blood

Samples of blood were collected from 10 representative cows in each group at monthly intervals from August 1941 to November 1946

Table 5. Percentage of protein in Paspalum plicatulum and Paspalum setaceum on fertilized plots, 1941-47

Treatment per acre	1941 June 20	1942 July 27	1942 Dec. 28	1943 Oct. 22	1944 June 22	1944 Oct. 22	1945 Sept. 20	1945 Nov. 14	1946 June 25	1946 Oct. 3	1947 Sept. 24	Average
Paspalum plicatulum												
800 lbs. triple superphosphate	7.45	5.67	5.20	[1]	6.42	4.50	11.35	4.50	9.54	6.75	3.55	6.49
400 lbs. triple superphosphate	7.84	6.15	4.70		5.13	3.85	10.00	4.74	11.17	8.02	3.70	6.53
200 lbs. triple superphosphate	7.49	6.15	5.11		5.74	3.80	10.55	5.28	9.85	6.55	3.45	6.40
100 lbs. triple superphosphate	7.54	5.73	5.16		6.74	5.00	9.48	5.85	9.66	6.50	3.60	6.33
164 lbs. potassium metaphosphate	6.74	5.47	5.30		5.05	3.81	10.70	5.70	9.90	7.11	4.05	6.38
162 lbs. calcium metaphosphate	7.09	5.38	4.54		4.80	5.29	11.70	5.90	9.88	8.65	3.70	6.69
None	8.35	5.67	4.93		5.32	3.90	9.80	6.70	10.50	8.48	5.00	6.86
Paspalum setaceum												
800 lbs. triple superphosphate	7.38	5.43	6.87	6.05	6.54	3.90	11.48	4.21	8.69	6.10	4.50	6.47
400 lbs. triple superphosphate	6.55	5.69	6.55	5.73	6.13	3.70	10.28	4.37	8.87	6.50	3.70	6.18
200 lbs. triple superphosphate	5.70	5.54	6.41	5.95	5.55	4.58	11.25	4.36	9.14	6.88	4.30	6.33
100 lbs. triple superphosphate	6.12	5.82	6.55	5.90	5.74	4.30	10.78	4.01	9.80	6.52	4.30	6.35
164 lbs. potassium metaphosphate	5.97	5.75	6.27	6.40	4.55	4.75	11.38	4.72	9.36	7.35	4.22	6.43
162 lbs. calcium metaphosphate	5.62	5.25	6.49	6.01	4.95	4.86	12.28	4.53	8.87	7.20	3.72	6.34
None	6.88	5.73	6.37	7.05	4.27	4.20	10.58	6.00	8.50	8.15	4.40	6.56

[1]Analysis of this species not obtained on this date.

for the determination of inorganic phosphorus. The amounts of phosphorus in these samples, expressed as milligrams (mg) per 100 cc of whole blood, are given in Table 7.

The average phosphorus content of the blood of the cows of each group was about 4 mg or higher in 1941 and 1942. Since this level of phosphorus was found in young cattle making satisfactory development, it is assumed that such levels indicate adequate phosphorus nutrition.

There was a sharp decline in the blood phosphorus in all groups soon after calving began in December 1942. The blood phosphorus of the cows in group 1, which were not fed a phosphorus supplement, continued to drop until August 1943, and, in general, was lower than that of groups 2, 3 and 4 during the remainder of the experiment. Symptoms of creeps, or phosphorus deficiency, were common in lactating cows in group 1. The low level of blood phosphorus and symptoms of phosphorus deficiency indicated that the cows did not receive adequate phosphorus nutrition. The pasture provided adequate nutrition for the development of heifers but did not permit an adequate level of phosphorus for lactation.

The blood phosphorus content of the cows in group 4, on the fertilized pasture, was higher than that of the cows in group 1, except in the winter of 1945 and 1946. The cows in this group did not show symptoms of phosphorus deficiency except in the drouth of 1945 and in the winter of 1945-46. The cows in group 4 had 55 calves in 1946 and the cows in group 1 had only 10. The stocking rates for groups 1 and 4 and the dry summer of 1945 greatly reduced the amount of pasturage and consequently the amount of phosphorus available. This may account for symptoms of creeps in these groups; however, the conditions were more severe in group 1 than in group 4, as shown by the number of calves in the latter group.

Group 3, which received disodium phosphate in water, maintained a high level of blood phosphorus and did not show evidence of creeps. After 1942, except from November 1943 to May 1944, the blood phosphorus of this group was higher than in any other group. In that period, pond water following rains was available to the cows.

The greatest difference for group 3 was the high level of blood phosphorus in June, July, August and September. This is a period in which

Table 7. Milligrams of inorganic phosphorus per 100 cc. of whole blood by months and years

Month	1941	1942	1943	1944	1945	1946	Av.[1]	1941	1942	1943	1944	1945	1946	Av.[1]
	Group 1. No phosphorus supplement							Group 2. Bonemeal self-fed						
Sept.	4.2	4.6	2.7	3.4	2.9	4.6	3.64	4.1	4.5	4.1	4.5	4.7	4.1	4.38
Oct.	5.2	4.3	3.8	4.3	3.4	4.2	4.00	5.2	5.1	3.8	5.0	4.4	4.3	4.52
Nov.	4.8	4.4	2.8	3.0	3.2	3.6	3.40	4.5	4.2	4.5	4.5	5.1	4.8	4.62
Dec.	3.7	3.6	3.2	2.8	2.1	—	2.92	3.4	3.9	5.0	5.3	3.1	—	4.32
Jan.	—	3.9	3.3	3.5	2.8	3.0	3.30	—	4.4	4.1	4.1	4.4	3.9	4.18
Feb.	—	4.0	3.2	3.7	3.8	2.2	3.38	—	4.8	3.2	4.5	4.2	4.1	4.16
Av.	—	4.13	3.17	3.45	3.0	3.52	3.44		4.48	4.12	4.65	4.32	4.24	4.36
March	—	3.7	2.6	3.0	3.7	2.9	3.18	—	3.9	2.8	3.1	4.5	3.4	3.54
April	—	3.8	3.0	3.0	3.0	2.5	3.06	—	4.1	3.6	4.1	5.0	3.9	4.14
May	—	4.2	2.9	2.8	3.6	3.0	3.30	—	4.3	3.8	4.3	4.9	5.6	4.58
June	—	3.9	2.8	2.6	2.8	3.8	3.18	—	4.6	3.9	4.2	4.6	4.5	4.36
July	—	4.4	2.6	2.1	2.8	2.6	2.90	—	4.6	4.0	3.8	5.0	3.4	4.16
Aug.	3.8	3.9	2.3	2.6	2.6	2.5	2.78	4.1	4.6	3.5	4.3	4.7	4.8	4.38
Av.		3.98	2.70	2.68	3.08	2.88	3.06		4.35	3.69	3.97	4.78	4.27	4.19
Av. 12 mos.		4.06	2.93	3.07	3.06	3.17	3.25		4.42	3.86	4.31	4.55	4.25	4.28
	Group 3. Disodium phosphate supplied in water							Group 4. Pasture fertilized with superphosphate						
Sept.	4.3	4.3	4.2	4.5	6.0	5.5	4.90	5.2	5.2	4.9	5.8	3.9	5.2	5.00
Oct.	5.0	5.2	4.5	5.8	4.7	4.1	4.86	5.6	5.1	5.2	5.0	5.1	4.4	4.96
Nov.	4.9	5.0	4.0	4.8	5.1	5.0	4.78	5.9	4.8	4.5	4.1	4.1	4.1	4.32
Dec.	3.6	5.0	3.8	5.0	4.7	—	4.62	4.3	4.7	4.1	3.6	2.4	—	3.70
Jan.	—	4.4	3.4	3.5	4.6	4.6	4.10	—	4.6	3.7	5.0	3.7	2.3	3.86
Feb.	—	4.0	4.1	4.4	4.8	4.1	4.28	—	4.7	3.8	4.6	4.0	2.3	3.88
Av.	—	4.65	4.00	4.67	4.98	4.66	4.59	—	4.85	4.37	4.68	3.87	3.66	4.29
March	—	4.0	4.1	2.5	4.1	3.9	3.72	—	4.3	4.1	4.1	4.3	2.7	3.90
April	—	4.3	3.7	3.4	5.2	5.1	4.34	—	4.9	4.1	4.6	4.3	2.3	4.04
May	—	4.8	3.7	4.4	5.7	5.4	4.80	—	5.3	4.4	4.0	4.1	3.1	4.18
June	—	4.0	5.1	4.8	5.7	4.9	4.90	—	4.8	4.6	3.7	3.7	3.7	4.10
July	—	4.8	5.5	5.6	6.9	4.8	5.52	—	5.3	3.7	3.0	3.6	3.0	3.72
Aug.	4.4	5.4	4.9	5.1	6.2	6.2	5.56	4.3	5.1	3.5	3.6	2.7	3.7	3.52
Av.		4.55	4.50	4.30	5.63	5.05	4.81		4.95	4.07	3.83	3.78	3.08	3.91
Av. 12 mos.		4.60	4.25	4.48	5.31	4.87	4.70		4.90	4.22	4.26	3.82	3.35	4.10

[1]1941 results not included in averages.

the calves made heavy demands on the cows, when seasonal lows in phosphorus content of vegetation may occur and when the consumption of water is increased by hot weather. With phosphorus intake proportional to the amount of water consumed, it follows that the blood level should be high. The lowest average values for blood phosphorus were found in December, January, February and March, a period in which cooler weather decreased the consumption of water.

Group 2, fed bonemeal, had a stable and relatively safe level of blood phosphorus throughout the experiment. In a few instances, cows with calves apparently did not consume enough bonemeal to meet minimum phosphorus requirements and showed evidence of "creeps." The average blood phosphorus level in this group was not as high as that for group 3, particularly in the summer. The differences were not as great during the winter, and both groups showed (Figure 3) their lowest blood phosphorus levels in March.

The greatest variation in monthly blood phosphorus levels was noted in group 3 and the least in group 2. There was slightly more variation in group 1 than in group 2 and almost as much in group 4 as in group 3. The limited variation in group 2 indicates that the cows tended to balance the consumption of bonemeal with the seasonal supply of phosphorus in the vegetation. Greater variation in group 3 is believed to have resulted from differences in water consumption and the use of a constant percentage of phosphate in water. Group 1 had less chance to show variation because of the limited phosphorus supply. Most of the calves were dropped ahead of the time of most abundant pasturage, thus, the demand on the cows tended to coincide with feed and phosphorus supply. The variation in group 4 seemed to reflect the phosphorus content of the vegetation as influenced by available moisture.

Table 7 shows that cows which received phosphorus supplements had more inorganic phosphorus in their blood than cows which did not receive the supplements, and indicates that phosphorus may be supplied satisfactorily through self-feeders, in a controlled water supply and through pasture fertilization. Supplying phosphorus in self-feeders and in a controlled water system maintained a higher level of blood phosphorus than pasture fertilization, but pasture fertilization maintained an adequate level except during drouth.

Phosphorus Intake of Cows in Groups 2 and 3

Cows in group 2 were fed bonemeal in self-feeders and cows in group 3 were supplied disodium phosphate in a controlled water supply. The average daily consumption of phosphorus in grams per cow by 28-day periods from July 30, 1941 to November 12, 1946, is shown in Table 8. The phosphorus supplements consumed by the calves were charged to the cows.

The disodium phosphate contained 8.74 percent of phosphorus and the bonemeal 10 percent.

Figure 2. Group 1 cows, no mineral supplement, February 1946. The cows averaged 882 pounds in December 1945. Only about 50 percent of the cows dropped calves in 1946, and many of the calves were late.

Figure 3. Group 2 cows, fed bonemeal, in February 1946. The cows averaged 1,140 pounds in December 1945. Most of the cows were in good flesh and several calves had been dropped although few are shown.

From July 30, 1941 to July 29, 1942, 20 pounds of disodium phosphate were used per 1,000 gallons of water. The amount was increased to 27.5 pounds from the latter date to June 2, 1943, reduced to 20 pounds until April 5, 1944 and increased to 27.5 pounds for the remainder of the experiment.

Group 2 consumed small amounts of bonemeal until after the start of calving in December 1942. Consumption averaged 6.0 grams of phosphorus daily per head in 1943 and 1944, but increased to more than 8.0 grams in 1945 and to 12.0 grams in 1946. After 1941, much larger amounts of bonemeal were consumed from March to September than from September to March. The demand of the calves, or lactation, is a factor affecting the consumption of bonemeal. Apparently, the cows eat bonemeal in an effort to maintain body reserves of phosphorus and not because it is palatable.

Phosphorus consumed by group 3 followed the same trend as that of group 2, but at a higher

Table 8. Grams phosphorus intake daily per cow by 28-day periods, 1941-46

Period	1941[1]	1942	1943	1944	1945	1946	Av.[1]	1941	1942	1943	1944	1945	1946	Av.[1]
	Group 2. Bonemeal in self-feeders							Group 3. Disodium phosphate in water						
8/27-9/24	.63	2.19	7.16	5.01	6.86	7.28	5.70	2.37	9.23	7.73	7.86	11.80	7.78	8.88
9/24-10/22	.63	3.62	4.12	3.09	2.71	6.52	4.01	2.34	6.03	2.06	6.21	6.23	2.86	4.68
10/22-11/19	2.83	1.36	5.66	5.81	7.54	8.10	5.69	2.01	4.65	3.37	7.24	8.56	4.03	5.57
11/19-12/17	2.83	4.30	3.24	6.90	9.46	——	5.98	1.78	7.78	1.96	5.53	7.04	——	5.58
12/17-1/14	3.77	3.88	4.94	7.99	11.39	——	7.05	1.12	4.52	1.38	6.54	6.34	——	4.70
1/14-2/11	——	3.77	3.54	3.81	6.37	9.99	5.50	——	1.05	3.69	2.87	5.81	5.39	3.76
2/11-3/11	——	1.88	3.20	1.28	.75	8.18	3.06	——	3.39	6.82	3.24	5.12	7.72	5.26
Average		3.00	4.55	4.84	6.44	8.01	5.28		5.24	3.86	5.64	7.27	5.56	5.49
3/11-4/8	——	1.88	5.13	3.77	7.92	15.15	6.77	——	3.39	7.35	2.53	6.61	11.17	6.21
4/8-5/5	——	3.77	5.99	10.38	7.16	15.83	8.63	——	4.12	11.88	9.51	8.90	12.60	9.40
5/5-6/3	——	7.54	8.86	9.16	11.50	31.44	13.70	——	5.11	13.39	10.86	14.19	10.78	10.87
6/3-7/1	——	3.77	5.66	7.95	8.86	11.87	7.62	——	5.97	13.36	12.75	15.96	7.17	11.04
7/1-7/29	——	3.77	7.92	5.54	15.72	9.99	8.59	——	6.03	15.25	16.13	15.26	13.54	13.24
7/29-8/26	.63	5.99	10.56	8.97	10.85	7.79	8.83	2.57	11.20	12.82	16.26	15.64	11.75	13.53
Average		4.45	7.35	7.63	10.34	15.34	9.02		5.97	12.34	11.34	12.76	11.17	10.72
Av. 13 periods		3.67	5.84	6.13	8.24	12.01	7.01		5.57	7.77	8.27	9.80	8.62	7.90

[1]1941 results not included in averages.

level. There was less variation in phosphorus intake by periods for group 2 than for group 3. Group 3 showed a much higher intake than group 2 in the summer but not in the winter. The trend in intake was upward by years and was much greater from March to September than from September to March. High intake in summer, or during the approximate period of greatest need, appears to be one advantage of supplying phosphorus in water.

Both groups of cows showed higher intakes of phosphorus than the 6.5 grams daily per head which was used as a standard at the beginning of the experiment. The results indicate that, in addition to the phosphorus received from the feeds, 7 to 8 grams should be supplied during periods of low demand imposed by the calves and 14 to 16 grams in periods of high demand, the latter occurring in the spring and summer. It has been observed that cattle prefer a phosphated water supply and that they are able to find such supply just as they are able to find phosphated areas in pastures.

Weights of Cows and Calves

The average initial and succeeding weights of cows and calves are shown in Table 9. The months in which the calves were dropped and the numbers of cows and calves by years are shown in Table 10. The cows began calving in December 1942 and the calves were weaned at approximately 240 days of age.

The average weight of 706 pounds for the heifers at the beginning of the experiment, July 30, 1941, and the average weight of 1,089 pounds, November 18, 1942, indicate excellent growth and condition just before the start of calving.

On November 17, 1943, group 1, which did not receive supplemental phosphorus, showed an average weight loss of 161 pounds per head from the year before. Group 2, fed bonemeal, and group 4, on the fertilized pasture, had minor losses of 58 and 38 pounds per head, respectively. Group 3, which received disodium phosphate in water, did not lose weight.

Table 9. Average weights in pounds per head of cows and weaning weights of calves by years

Time	Group 1, no phosphorus supplement		Group 2, self-fed bonemeal		Group 3, disodium phosphate in water		Group 4, pasture fertilized	
	Cows	Calves	Cows	Calves	Cows	Calves	Cows	Calves
7/30/41[1]	706		708		708		705	
11/18/42[2]	1077		1087		1050		1142	
11/17/43[3]	916		1029		1051		1106	
12/13/44	867		1107		1103		1160	
12/12/45	882		1140		1155		1107	
11/12/46	1047		1148		1195		1109	
1943[4]	774	500	939	524	956	529	993	544
1944	825	500	1043	516	1028	533	1052	562
1945	789	460	1015	545	1039	519	1007	557
1946	878	497	1048	556	1099	590	1007	542
Average	802	489	1011	535	1029	542	1015	551

[1]Initial weight.
[2]Weight before start of first calving in December 1942.
[3]Weight of cows in late fall.
[4]Weight of cows and calves when calves were weaned.

At the succeeding fall weighings in 1944, 1945 and 1946, cows in groups 2, 3 and 4 had very few calves at side. Group 1 was not comparable with groups 2, 3 and 4 in this respect after the first year because of later calving and a lower percentage calf crop. The marked increase in weight for group 1 in 1946 resulted because less than half the group raised calves. Groups 2 and 3 showed small, but steady increases in weight from 1943 to 1946. Group 4 weighed the same in 1946 as in 1943, but showed a gain from 1943 to 1944. The average weights of cows in groups 2, 3 and 4 indicate cows of good size, but the effect of drouth and a decreased supply of phosphorus is indicated for group 4 in 1945 and 1946.

The average birth date of calves from groups 2, 3 and 4 was February 1 and the averages of the respective groups varied only from January 18 to February 25. The average birth date for group 1 calves was March 26 and the range was from January 23 in 1943 to May 16 in 1946.

Figure 4. Group 3 cows, fed disodium phosphate in water, February 1946. The cows averaged 1,155 pounds in December 1945. The cows were strong and in good flesh. Numerous young calves of the 1946 crop are at side.

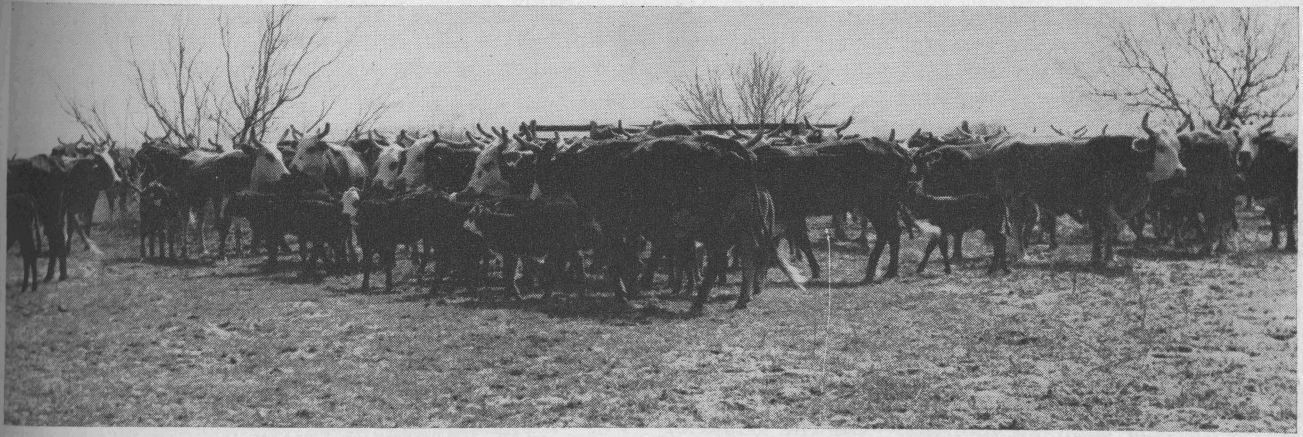

Figure 5. Group 4 cows, on pasture fertilized with superphosphate, February 1946. The cows averaged 1,107 pounds in December 1945. Note the large number of young calves and that the cows are big, although some are thin.

The weights of cows just before calving should be near the greatest of the year and at weaning about the least. Group 1 showed a loss of 303 pounds per head from November 1942 to the date calves were weaned in 1943. Only 142 pounds of this loss were regained by November 1943. Groups 2 and 4 showed nominal losses of about 150 pounds, most of which was regained in the period between weaning and calving. Groups 2 and 3 weighed about 200 pounds more per head than group 1 from 1943 to 1946. Group 4 had such an advantage except in 1946, when group 1 averaged only 125 pounds lighter.

A high potential of production is indicated for the experimental area under favorable conditions, since the first calves of group 1 averaged 500 pounds per head when weaned at 240 days. Although the cows in group 1 lost weight in raising the calves dropped in 1943, their calves dropped in 1944 also averaged 500 pounds at weaning. In 1945, the calves averaged 460 pounds, but the summer was dry and many of them were late. Weaning weights were consistently above 500 pounds for groups 2, 3 and 4 and tended to increase. The calves in group 3 had an average weight of 590 pounds in 1946.

Table 10. Months in which calves were dropped and numbers of cows and calves by years

Year	Number of cows	% calf crop	Average calving date	Number of calves dropped												
				Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Group 1. No phosphorus supplement																
1942-43	43	90.7	1/23/43	6	27	3	—	2	—	1	—	—	—	—	—	39
1943-44	42	90.5	3/17/44	1	5	8	12	8	—	1	1	1	—	—	1	38
1944-45	42	76.2	4/14/45	1	—	1	2	18	4	3	—	—	1	—	2	32
1945-46	40	48.0	5/16/46	1	2	1	1	—	1	5	2	3	1	2	—	19
Total or average	41.8	76.4	3/26	9	34	13	15	28	5	10	3	4	2	2	3	128
Group 2. Bonemeal self-fed																
1942-43	43	93.0	2/3/43	3	20	9	6	2	—	—	—	—	—	—	—	40
1943-44	43	93.0	2/25/44	1	7	17	11	3	—	—	—	1	—	—	—	40
1944-45	43	95.3	2/17/45	3	19	9	2	3	—	—	2	2	—	—	1	41
1945-46	40	92.5	1/27/46	12	18	1	2	1	—	—	—	1	2	—	—	37
Total or average	42.2	93.4	2/10	19	64	36	21	9	—	—	2	4	2	—	1	158
Group 3. Disodium phosphate supplied in water																
1942-43	42	102.4	1/22/43	6	30	3	—	—	2	—	1	—	—	—	1	43
1943-44	42	102.4	2/2/44	11	18	2	4	1	2	—	1	—	1	—	3	43
1944-45	42	97.6	1/29/45	18	5	1	7	2	1	2	—	1	—	—	4	41
1945-46	40	92.5	1/30/46	19	5	4	3	—	3	—	1	—	—	2	—	37
Total or average	41.5	98.7	1/28	54	58	10	14	3	8	2	3	1	1	2	8	164
Group 4. Pasture fertilized with triple superphosphate																
1942-43	62	101.6	1/20/43	10	41	3	3	3	—	—	1	—	—	—	2	63
1943-44	57	107.0	1/24/44	22	17	4	5	1	5	—	1	—	—	2	4	61
1944-45	57	115.8	1/18/45	25	9	4	1	3	4	—	1	1	—	2	16	66
1945-46	57	91.2	2/23/46	19	9	4	2	2	2	—	1	—	2	6	5	52
Total or average	58.2	103.9	1/29	76	76	15	11	9	11	—	4	1	2	10	27	242

Calves in group 4 were uniform in weight each year. Seasonal influences on production were much the same for groups 2, 3 and 4 because of the rather uniform calving and weaning dates.

Calf Production

All of the fourth crop of calves and some of the fifth crop had been dropped in groups 2, 3 and 4 by November 1946. Few of the cows in group 1 dropped a fourth calf. The number of calves dropped by months, average date of calving and percentage of calves dropped per cow in the four 12-month periods are shown in Table 10.

Some cows in groups 2, 3 and 4 dropped calves in less than 12 months. On the basis of one calf per cow in 12 months as a 100 percent calf crop, group 4 exceeded 100 percent in the first 12-month periods and averaged 103.9 percent for the four periods. Group 3 averaged 98.7 percent for the four periods; group 2, 93.4 percent; and group 1, 76.4 percent.

The cows in groups 2, 3 and 4 rebred and settled with calf much more readily than those in group 1.

Cows in group 1 tended to miss calving and calved later in the year. Cows in group 2 maintained regular calving, with only 10 out of 161 calves in the four periods being dropped later than May. Group 3 had a scattering of calves through the different months, but most of the cows had calves in December and January. The shift of calving from January to December was definite in the last 2 years. The cows in group 4 also dropped calves from May through September, but there was a definite increase in the earliness of the calves. In this group, fall calves began to appear in the third and fourth years and composed 25 percent of the calves dropped.

Production and Returns

The comparative production and costs of supplements for the four groups of cows from July 30, 1941 to November 12, 1946, are summarized in Table 11. The costs and returns are based on the average number of cows in the groups during the 4 years of production. Forty of the 43 cows originally placed in groups 1, 2 and 3, and 57 of the 62 cows in group 4 completed the experiment.

The number of calves weaned and on which returns were calculated differed from the number dropped. While a few calves died, most of the difference was due to late calving in 1946. Calves dropped after June 1 were not considered in the returns. The cows that were lost in the experiment were replaced to maintain the original stocking rates, but their calves were not used in computing the returns.

The four groups started at the same weight in July 1941 and all made satisfactory growth up to calving, which began in December 1942. The respective average weights in late fall were 1,077, 1,087, 1,050 and 1,142 pounds. At subsequent weighings, cows in group 1 were approximately 200 pounds lighter than the others. The cows in group 3 were the heaviest at the close of the experiment, with an average weight of 1,195 pounds. Groups 2 and 4 followed with average weights of 1,148 pounds and 1,109 pounds per head, respectively. However, the weights of the

Table 11. Summary of production, costs and returns, 1941-46

Item	Group 1, no phosphorus supplement	Group 2, bonemeal in self-feeders	Group 3, disodium phosphate in water	Group 4, pasture fertilized with triple superphosphate
Acres in pastures	575	681	586	684
Average number of cows	41.8	42.2	41.5	58.2
Acres per cow	13.8	16.1	14.1	11.8
Initial weight as heifers July 30, 1941, lbs.	706	708	708	705
Final weight before calving, Nov., 1942, lbs.	1,077	1,087	1,050	1,142
Average fall weight, 1943-46, lbs.	928	1,106	1,126	1,121
Final weight Nov. 12, 1946, lbs.	1,047	1,148	1,195	1,109
Average weight at weaning time, 1943-46, lbs.	802	1,011	1,029	1,015
Number of calves dropped	128	158	164	242
Number of calves weaned	109	148	154	219
Weight of calves at weaning time, lbs.	489	535	542	551
Value of weaned calf at $15 per 100 lbs.	$73.35	$80.25	$81.30	$82.65
Total weight of calves weaned in 4 years, lbs.	53,340	79,166	83,516	120,704
Total calf weight weaned per cow, lbs.	1,276	1,876	2,012	2,074
Total calf weight weaned per acre, lbs.	93	116	143	176
Total phosphorus supplement or fertilizer, tons	—	6.02	7.73	56.64
Cost of supplement or fertilizer per cow[1]	—	$8.56	$13.97	$76.37
Cost of supplement or fertilizer per acre	—	$0.53	$ 0.99	$ 6.50
Total returns per group, calves at $15 per 100 lbs.	$8,001.00	$11,874.40	$12,527.40	$18,105.60
Return per cow less cost of supplement or fertilizer	$191.41	$272.84	$287.89	$234.72
Return per acre less cost of supplement or fertilizer	$13.91	$16.91	$20.39	$19.97

[1]Prices per ton: bonemeal, $60; disodium phosphate, $75; and triple superphosphate, $62.40, plus $1.50 per acre for application on 607 acres.

cows and pasture rent are not considered in the summary of production given in Table 11.

When the costs of phosphorus supplements and superphosphate were charged to the respective groups, the returns per cow were $191.41, $272.84, $287.89 and $234.72 for groups 1, 2, 3 and 4, respectively. The respective returns per acre were $13.91, $16.91, $20.39 and $19.97.

Group 3, which received disodium phosphate in water, had a consistent but small advantage over group 2, fed bonemeal, in final weight of cows, in number of calves dropped and weaned, in weight of calves and in returns per acre and per cow. Cows in group 2 consumed 285 pounds of bonemeal per head and cows in group 3 consumed 373 pounds of disodium phosphate.

Cows in group 1, which had no phosphorus supplement, were lighter, dropped fewer calves, were more irregular and slower to settle and weaned lighter calves than the cows which received supplemental phosphorus.

Group 4, which was on fertilized pasture, dropped approximately 48 percent more calves than group 3, 53 percent more than group 2 and 89 percent more than group 1. This group produced 44 percent more pounds of weaned calves than group 3, 52 percent more than group 2 and 126 percent more than group 1. Group 4 also had a small advantage over groups 2 and 3 in calf weight per cow, and a marked advantage over group 1. The principal advantage for group 4 was the greater number of calves. Approximately one ton of triple superphosphate was applied to the pasture for each cow in group 4.

DISCUSSION OF RESULTS

It was practical to supply phosphorus in self-feeders, in a controlled water supply and by fertilizing pasture with superphosphate. The returns per cow and per acre were greatest for group 3, which received disodium phosphate in water. Group 2, fed bonemeal, was second in returns per cow and group 4, on fertilized pasture, was second in returns per acre.

Fertilization with superphosphate permitted a higher rate of stocking and was effective in supplying phosphorus when rainfall was favorable. It was less effective as a source of supplemental phosphorus during drouth than phosphorus in self-feeders or in the drinking water.

The complete effect of fertilization probably was not realized because drouth closed the experiment in November 1946. Beneficial effect may have persisted for a longer time. However, chemical analyses of forage, soil and blood (Tables 6 and 7) and cases of creeps in the cows indicated a marked decline in available phosphorus during the last 18 months of the experiment.

There was ample forage in the pastures until drouth began in 1945. Afterward, there was evidence of over-stocking, particularly in pasture 4. Pastures 1 and 4 were stocked with 1 cow to approximately 14 and 12 acres, respectively, but the cows in the latter pasture were about 200 pounds heavier after the first calving and raised more calves. On the basis of 900-pound cows, pasture 1 carried 42 cows; pastures 2 and 3, 50 cows each; and pasture 4, 70 cows. The phosphorus supplements and pasture fertilization, by increasing weights of cows and their production, imposed heavier rates of pasture use. Thus, it follows that, in addition to the number of head, production and weight are factors that should be considered in stocking.

SUMMARY AND CONCLUSIONS

An experiment was conducted on the Encino division of the King ranch near Falfurrias from 1941 to 1946 to determine the most practical methods of supplying phosphorus to range cattle and to determine the effect of applications of different phosphates on the yield and chemical composition of pasture forage. Phosphorus was supplied to cattle by feeding bonemeal in self-feeders, by adding disodium phosphate to a controlled water supply and by fertilizing pasture with triple superphosphate.

Supplying phosphorus by all three methods gave good results and prevented phosphorus deficiency in normal seasons. The specific application of these findings, however, may be somewhat different, depending on the circumstances. For example, some ranchmen will find it feasible to supply phosphorus in a controlled water system. Others may find it more praticable to supply phosphorus supplements in self-feeders. Still others may prefer to supply phosphorus through pasture fertilization. The results show conclusively that the cattle will get the necessary phosphorus where any of these methods is used.

Cows that were fed phosphorus supplements and cows on fertilized pasture produced larger calf crops and heavier calves at weaning time than cows that did not receive phosphorus supplements. The cows that did not receive phosphorus supplements produced 93 pounds of weaned calves per acre; cows that were fed bonemeal, 116 pounds; cows that received disodium phosphate in drinking water, 143 pounds; and cows on fertilized pasture, 176 pounds.

Cows that did not receive a phosphorus supplement yielded a gross return of $13.91 per acre for the 4 years. After deducting the cost of phosphorus supplements or fertilizer, the cows that were fed bonemeal gave a return of $16.91 per acre; cows that received disodium phosphate in water, $20.39; and cows on fertilized pasture, $19.97.

Feeding phosphorus supplements also greatly increased the amount of inorganic phosphorus in the blood stream. Supplying phosphorus in self-feeders and in a controlled water system, in general, maintained a slightly higher level of blood phosphorus than pasture fertilization. Pasture fertilization, however, maintained an adequate phosphorus level in the blood stream except during the prolonged drouth in 1945 and 1946.

If pasture fertilization is used, it probably will be necessary to reduce the rate of stocking and feed phosphorus supplements during drouth to supply adequate phosphorus to the cattle. This system of management will utilize all the advantages of pasture fertilization and, at the same time, provide sufficient phosphorus for cattle at all times.

Applications of triple superphosphate, calcium metaphosphate, potassium metaphosphate and fused tricalcium phosphate increased the yield and phosphoric acid content of pasture forage. The increases in yield ranged from 33 to 84 percent, depending on the rate of application. Pound for pound of phosphoric acid, all the phosphates used apparently had about the same fertilizing value.

In general, the phosphoric acid content of the grasses increased as the rate of phosphate application was increased. The heavier applications of triple superphosphate doubled the phosphoric acid content of the grasses and provided adequate phosphorus for range cattle in normal seasons.

The application of phosphates apparently did not affect the protein content of grasses.

The application of approximately 200 pounds of 48 percent triple superphosphate per acre in 1941 was effective in increasing the yield and phosphorus content of pasture forage for 4 or 5 years. This amount of phosphate was profitable and is recommended where ranchmen can use it to advantage.

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