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Supplemental Phosphorus Requirement of Range Beef Cattle

In North Central and Southeastern Oklahoma

by
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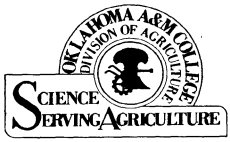
O. B. Ross, and A. E. Darlow



Agricultural Experiment Station
DIVISION OF AGRICULTURE
Oklahoma A. and M. College
Stillwater

This bulletin reports that . . .

- **A mineral phosphorus supplement is beneficial for the production of beef cattle, both winter and summer, in southeastern Oklahoma.**

  Phosphorus supplementation effectively promoted the growth of calves and increased the weights of cows, in a four-year study at Wilburton. (However, the perfomance of all cows that produced calves was considered below normal, which indicated that other factors influenced the performance of the cows in that area.)

  Phosphorus supplementation also increased the phosphorus in the blood plasma of cows, particularly during the winter.

  In this area the minimum phosphorus requirement of range beef cows was more than 7 gm per head per day and might possibly be as high as 12 gm.

- **In normal years, phosphorus supplementation of beef cattle is not necessary in north central Oklahoma. However, in dry years a phosphorus supplement will provide a margin of safety.**

  Feeds and grasses grown in north central Oklahoma supplied sufficient phosphorus for normal growth and reproduction of beef cattle, during a four-year study at Stillwater.

  The phosphorus requirement for growth, reproduction, and lactation in this area was apparently met by an intake of approximately 7 gm per head daily during the winter, 9 gm in early summer, and 6 gm during late summer.

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In North Central and Southeastern Oklahoma[1]

By
A. B. Nelson, W. D. Gallup
O. B. Ross, and A. E. Darlow[2]

Phosphorus is one of the most important mineral elements required by beef cattle for good growth and production. To make sure that cattle receive an adequate amount, especially in areas where soils and forage are deficient in phosphorus, it is a common practice to feed a mineral phosphorus supplement.

In central Oklahoma, some soils are bordering on a phosphorus deficiency, while many of those in southeastern Oklahoma are definitely phosphorus deficient. Since the production of beef cattle in Oklahoma represents a major source of income, it is important that producers know whether or not a phosphorus deficiency exists in their area and, if so, how much phosphorus supplement should be fed.

A long-time experiment was initiated in 1947 to determine the supplemental phosphorus requirement of range beef cattle grazed in north central and in southeastern Oklahoma. Among the observations made in the experiment were:

- The effect of three different levels of phosphorus intake on the growth and reproductive performance of the cattle at each area.
- The effect of phosphorus intake on certain constituents of the blood of cattle.
- The seasonal change in phosphorus and other constituents of native pasture grasses growing in each area.

[1] Partially supported by a grant from Swift and Company, Chicago, Illinois.
[2] Respectively: Associate Animal Husbandman, Nutrition; Research Chemist; formerly Animal Husbandman, Nutrition; formerly Head, Department of Animal Husbandry, and now Dean of Agriculture and Vice-President, Oklahoma A. & M. College. The greater part of the chemical work in this experiment was done by Myron E. Gibson, former assistant in the Department of Agricultural Chemistry Research. Others associated with the work were W. B. Robertson, J. A. Nance, W. D. Campbell, and J. Kinnikin.

How Tests Were Made

Two areas of the state were selected for the study; one where soils are bordering upon phosphorus deficiency (Lake Carl Blackwell Experimental Range Area near Stillwater), and the other where the soils are definitely phosphorus deficient (Range Cattle Minerals Station near Wilburton). Approximately 640 acres of grassland were secured for grazing in each of the two areas. Adjoining areas were secured for production of native grass hay to be used for winter feeding.

Each experimental area was stocked with 30 head of bred two-year-old grade Hereford heifers and 30 weanling heifer calves. The heifers and calves were handled separately. The test began in January, 1947, and ended in October, 1950. Each age group of cattle was divided into three lots of 10 head each and fed low, medium, and high phosphorus rations. The corresponding lots of cattle at each area were managed similarly and fed similar rations.

During the winter feeding period, from early November to mid-April, the cattle were confined to small traps and fed prairie hay, free choice, and 1.25 pounds of protein supplement per head, daily. The average daily consumption of hay and protein supplement during the winter are shown in Table I. Corn gluten meal was selected as the protein supplement to provide a ration adequate in protein but relatively low in phosphorus content. During the remainder of the year the different lots of cattle were allowed to graze in separate pastures. The lots were rotated among the pastures to reduce possible variation due to pasture differences. Salt was available at all times.

Table I.—Average Daily Consumption of Hay and Protein Supplement During Winter.

(pounds)

Animals and Feed	Stillwater			Wilburton		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
Heifers						
Prairie hay	10.60	10.62	10.64	11.74	12.82	12.56
Corn gluten meal	1.31	1.31	1.31	1.24	1.24	1.24
Cows						
Prairie hay	15.57	15.64	15.63	15.02	17.06	16.64
Corn gluten meal	1.24	1.24	1.24	1.24	1.24	1.24

Lot 1[1]

Cattle of Lot 1 at each location, in the winter, received only the amount of phosphorus contained in the native grass hay and the protein supplement. In the summer, their only source of phosphorus was pasture grass.

Lot 2

Cattle of Lot 2 at each location were fed dicalcium phosphate[2] mixed with the corn gluten meal during the winter in an amount to provide a total daily intake of approximately 1.5 gm of phosphorus per 100 pounds live weight. During the summer, at Wilburton, they were allowed free access to a mineral mix of nine parts salt and one part dicalcium phosphate; at Stillwater they were not fed additional phosphorus since the grass supplied the desired amounts.

Lot 3

Cattle of Lot 3 at each location were fed dicalcium phosphate during the winter in an amount to provide a total daily intake of approximately 2.5 gm of phosphorus per 100 pounds live weight. During the summer they were allowed free access to a mineral mixture of two parts salt and one part dicalcium phosphate.

It was estimated that the phosphorus intake of the cattle in Lot 1 would be below that usually recommended for normal growth and reproduction, that the phosphorus intake of those in Lot 2 would be barely adequate, and that the phosphorus intake of Lot 3 would be more than adequate. These estimates were based on the average phosphorus content of grass and other feeds. The average amount of dicalcium phosphate fed during the winter and summer months to Lots 2 and 3 is shown in Table II. The estimated average daily intake of total phosphorus is given in Table III.

Registered Hereford bulls were in the pastures with the cows from May 1 to September 1 of each year. The bulls were rotated among the lots of cows at regular intervals. The weanling heifer calves at the start of the experiment were bred as two-year-olds to calve at three years of age, thus increasing the number of cows per lot during the third and fourth years of the test.

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[1] Initially, each lot of cattle was made up of an equal number of bred heifers and calves. Throughout the experiment these two age groups within each lot were handled separately.

[2] The composition of dicalcium phosphate is similar to bone meal. It was used in these studies to provide a relatively pure source of phosphorus (and calcium) uncontaminated with other minerals.

Table II.—Average Daily Consumption of Mineral Phosphorus Supplement[1]

(grams)

Animals and Season	Stillwater		Wilburton	
	Lot 2	Lot 3	Lot 2	Lot 3
Heifers				
In winter	17.6	46.8	10.8	40.3
In summer	0.0	2.0	2.3	5.1
Cows				
In winter	27.2	72.6	23.8	60.1
In summer	0.0	3.4	2.8	7.9

[1] Dicalcium phosphate. Its composition is similar to bone meal.

Table III.—Estimated Average Daily Intake of Total Phosphorus.[1]

(grams)

Animals and Season	Stillwater			Wilburton		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 3	Lot 2
Heifers						
In winter	5.86	9.07	14.37	5.98	8.22	13.51
In early summer	6.16	6.16	6.52	6.10	6.52	7.06
In late summer	3.81	3.81	4.17	3.27	3.69	4.23
Cows						
In winter	6.95	11.91	20.15	6.81	11.65	18.13
In early summer	9.23	9.23	9.85	9.15	9.67	10.59
In late summer	5.72	5.72	6.34	4.90	5.42	6.34

[1] The phosphorus intake in winter was calculated from weighed amounts of feeds. The phosphorus intake in early and late summer was calculated from the average daily mineral phosphorus consumption for the entire summer, phosphorus content of samples of grass collected in season, and an assumed daily intake of 18 pounds of dry matter, as grass, by cows and 12 pounds by heifers.

Samples of blood for chemical analysis were taken from the cattle in all lots at approximately 56-day intervals. Samples of grass for analysis were collected from the pastures throughout the grazing season. These samples, which were cut 3 to 4 inches above the ground, represented the predominant species; they were mostly little bluestem, big bluestem, and Indian grass. Representative samples of native grass hay, corn gluten meal, and mineral supplements were secured from the area where they were produced for analysis at the beginning of each winter feeding period.

From the results of these analyses, calculations were made of the phosphorus intakes of the cattle during the winter and throughout the grazing season. These calculations were based on known amounts of hay, protein supplement, and dicalcium phosphate fed in winter, and estimated amounts of grass and dicalcium phosphate consumed in

summer. Throughout the summer months, grass consumption in terms of dry matter was estimated at 18 pounds per day for cows and 12 pounds per day for heifers. Average daily dicalcium phosphate consumption in summer was estimated by difference between the amount offered in salt boxes and the amount remaining at the end of the grazing season. That these estimates of phosphorus consumption in summer are subject to considerable error is recognized. By selective grazing, the cattle probably consumed appreciable amounts of grass of higher phosphorus content than that collected for chemical analysis. Also, total grass intake, which very likely varied from month to month, may have been more or less than was estimated.

To show the seasonal change in composition of grass at the two locations, analytical results obtained over a period of five years have been averaged and summarized in Table IV. At both locations, the protein and phosphorus content of the grass was relatively high in spring and low in late summer. Crude fiber content showed an opposite trend. At Stillwater, the phosphorus content of the grass decreased from 0.14 percent in May to 0.07 percent in September; at Wilburton, it decreased

Table IV.—Average Chemical Composition of Feeds[1] and Grasses[2].

Feeds and Grasses	Percent dry matter	Percentage composition of dry matter[3]						
		Ash	Crude protein	Ether extract	Crude fiber	N-free extract	Ca	P
			Stillwater					
Prairie hay	93.00	7.21	4.19	2.53	33.27	52.80	0.44	0.06
Corn gluten meal	94.00	3.99	45.71	2.20	3.78	44.32	0.21	0.57
Dicalcium phosphate	97.00	---	----	---	----	----	24.15	18.72
Grasses								
Spring months (May)		7.75	11.51	1.96	32.25	46.43	0.36	0.14
Summer months (June, July)		7.46	6.80	2.43	33.64	49.61	0.35	0.10
Late summer months (August, September)		5.83	4.65	2.19	36.66	50.67	0.32	0.07
			Wilburton					
Prairie hay	93.00	7.34	4.63	2.57	32.40	53.06	0.55	0.06
Corn gluten meal	94.00	3.99	45.71	2.20	3.78	44.32	0.21	0.57
Dicalcium phosphate	97.00	---	----	---	----	----	24.15	18.72
Grasses								
Spring months (April)		9.06	13.86	3.04	25.67	48.37	0.44	0.18
Summer months (May, June, July)		6.91	7.11	2.09	33.16	50.74	0.37	0.09
Late summer months (August, September)		7.60	4.50	1.86	34.10	51.94	0.41	0.06

[1] 1947-50.
[2] 1947-52.
[3] Values expressed as percent of dry matter because of the extreme changes in moisture content of grass during the grazing season.

from 0.18 percent in April to 0.06 percent in September. Throughout most of the grazing season, the average phosphorus content of the grass was only 0.01 percentage unit lower at Wilburton than at Stillwater. Hay from the two areas contained similar amounts of phosphorus, 0.06 percent; however, the Wilburton hay contained a higher proportion of weeds and undesirable grass species[1].

Results at Stillwater

Growth of heifers

The heifers in all lots made about equal gains during the first winter at Stillwater (Table V). During the second winter, the heifers which were not fed phosphorus supplement, Lot 1, lost 50 pounds; those fed the medium level of phosphorus, Lot 2, lost 27 pounds; and those fed the high level, Lot 3, gained an average of 19 pounds per head. The average total gain by the end of the second summer was 617 pounds for the heifers of Lot 1, 612 pounds for those of Lot 2, and 646 pounds for those of Lot 3. The heifers of Lot 2 consumed 17.6 gm of dicalcium phosphate per head daily during the winter. Those of Lot 3 consumed 46.8 gm during the winter and approximately 2 gm during the summer. All lots of heifers appeared healthy and vigorous. The results of determinations made on blood samples collected at regular intervals are given in Appendix Table I.

[1] Gibson, M. E., W. D. Gallup and O. B. Ross, 1950. Forage Composition in Relation to Phosphorus Deficiency in Range Beef Cattle in Southeastern Oklahoma. Proc. Oklahoma. Acad. Science 31:94.

Table V.—Growth of Heifers, Stillwater.
(pounds)

Lot number Phosphorus level[1]	1 Low	2 Medium	3 High
Average weight per head			
1-31-47	420	420	421
4-24-47	454	451	458
11-3-47	734	721	710
4-21-48	684	694	729
10-27-48	1037	1032	1069
Average gain per head			
Winter (4-24-47)	34	31	37
Summer (11-3-47)	280	270	252
Winter (4-21-48)	—50	—27	19
Summer (10-24-48)	353	338	340
Total gain per head			
(1-31-47 to 10-24-48)	617	612	646
Difference in gain compared to Lot 1		—5	29

[1] The consumption of dicalcium phosphate for the entire 21-month period was 12.3 and 31.0 pounds per head for the heifers in Lots 2 and 3, respectively.

Table VI.—Average Weights of Cows, Stillwater, 1947-50.
(pounds)

Date	Weights compared	Lot 1 Low P	Lot 2 Med P	Lot 3 High P
1-31-47	Initial	821	820	820
11-3-47	End of summer[1]	848	826	857
2-10-48	Prior to calving[2]	875	848	865
10-27-48	End of summer	1014	953	1003
10-27-48	End of summer[3]	987	961	991
2-15-49	Prior to calving	938	924	954
10-24-49	End of summer	1021	1001	1014
1-31-50	Prior to calving	1039	998	995
10-10-50	End of summer	1094	1053	1081

[1] End of summer grazing period. This weight was also the beginning of the winter feeding period except in 1948.

[2] Last weight obtained before any calves were born.

[3] Additional cows were placed in each lot at the beginning of the winter feeding period in October, 1948. The cows added were those from the respective lots fed three levels of phosphorus during the growth study summarized in Table IV.

Weights of cows

The cows in all lots increased in weight from year to year (Table VI and Appendix Table II). Their average initial weight was about 820 pounds, and at the end of the fourth summer they weighed between 1053 and 1094 pounds. There were no great differences between lots in gains made from the start of a particular winter feeding period until last weight was taken before any calves were born. The cows in all lots lost considerable weight during the winter period due to calving and lactation but these losses were offset by gains made during the summer. Apparently the level of dietary phosphorus did not affect the weight of the cows from year to year; consequently no definite trend was established. The cows of Lot 2 consumed 27.2 gm of dicalcium phosphate per head daily during the winter period. Those of Lot 3 consumed 72.6 gm of dicalcium phosphate per head daily during the winter and approximately 3.4 gm during the summer.

Calving Data

The produuction of the cows of all lots was satisfactory as measured by birth and weaning weights of calves (Table VII and Appendix Table III). Although in the four-year period, the cows not fed a phosphorus supplement produced the heaviest calves at weaning, those fed the medium and high levels of phosphorus weaned the largest number of calves. These differences between lots were small and may not be real, but like the differences obtained in growth of heifers, they favored slightly the phosphorus supplemented lots. Apparently

Table VII.—Summary of Calving Data, Stillwater, 1947-50.

Items compared	Lot 1 Low P	Lot 2 Med P	Lot 3 High P
Number of cows	61	63	63
Number of calves born	56	58	55
Number of calves weaned[1]	50	56	53
Average birth date of calves, March	19	23	18
Average birth weight of calves, lbs.[2]	72	73	72
Average weaning weight of calves, lbs.[3]	442	432	432

[1] The number of calves weaned as a percentage of number of cows was 82, 89, and 84 percent for Lots 1, 2, and 3, respectively.
[2] Corrected for sex.
[3] Corrected for sex and an age of 210 days.

Table VIII.—Average Plasma Phosphorus of Cows, Stillwater[1].
(mg/100 ml)

Lot Number	Phosphorus level	December[2]	February	April	June	August	October
1	Low	5.3	3.1	3.7	4.4	5.7	4.2
2	Medium	6.4	4.9	5.7	4.6	4.7	4.1
3	High	6.3	5.9	6.0	4.4	5.1	4.6

[1] Average of three years for all months except December.
[2] Average of two years.

the amount of phosphorus supplied in the feed alone (Lot 1) was barely adequate for average production.

Blood plasma phosphorus levels

A summary of the values which indicate the state of phosphorus nutrition of the animals is shown in Table VIII. During the winter the plasma phosphorus values were lowest for the cows fed the low level of phosphorus (Lot 1), intermediate for cows fed the medium level of phosphorus (Lot 2), and highest for those fed the high level of phosphorus (Lot 3). The lowest winter value, 2.2 mg phosphorus per 100 ml of plasma, was observed in the cows of Lot 1, February 2, 1948. Plasma phosphorus values for the cows of Lot 1 were usually higher during the summer grazing season than during the winter when phosphorus intake was low. The plasma phophorus values for the cows of Lots 2 and 3 were lower in the summer than in the winter. This latter difference is ascribed to difference in intake resulting from the manner of feeding the phosphorus supplement, i. e., free-choice in the summer and mixed with the protein supplement in winter. The plasma phosphorus levels were not low enough for any extended period of time to be considered critical. The average February value over a period of three years for Lots 1, 2, and 3 was 3.1, 4.9 and 5.9 gm, respectively. Detailed results of determination of various blood

constituents (phosphorus, calcium, carotene, vitamin A, hemoglobin, hematocrit, red blood cells, plasma protein, magnesium) are given in Appendix Table IV.

Minimum phosphorus requirement

Cows (Lot 1) that consumed 7.0 gm of phosphorus per head per day during the winter, and an estimated 9.2 gm during early summer and 5.7 gm during late summer performed well, although plasma phosphorus values dropped to less than 4 mg per 100 ml for a period of six months during one year and to less than 3 mg for 60 days of that period. Cows of Lot 2 that consumed 11.9 gm of phosphorus per head daily in winter (27.2 gm of dicalcium phosphate in addition to feed) performed only slightly, if any, better than those in Lot 1. Thus, the minimum phosphorus requirement appears to be close to the amount consumed by the cows of Lot 1.

These results have been confirmed in the Stillwater area with another group of cows managed like those of Lot 1 during the years 1950-54. As judged by performance during four years, their phosphorus requirements were met by the amount contained in native grass during the summer, and in the prairie hay supplemented with corn gluten meal during the winter. Their average phosphorus intake during the winter was 8 gm per head daily.

Results at Wilburton

Growth of heifers

The value of a high-phosphorus mineral supplement for growing heifer calves at the Wilburton location is quite apparent in the results shown in Table IX. In a 21-month period, the heifers fed no phosphorus supplement, Lot 1, gained 376 pounds; those of Lot 2, which consumed 10.8 gm of dicalcium phosphate per head daily during the winter and about 2.3 gm per head daily during the summer made an average gain of 483 pounds; those of Lot 3, which consumed 40.3 gm of dicalcium phosphate daily during the winter and approximately 5.1 gm during the summer, gained 541 pounds. A total of 26 pounds of phosphorus supplement fed over a period of 21 months resulted in a difference of 165 pounds in gain.

The heifers in both lots that were fed phosphorus supplements were in considerably better flesh, healthier in appearance, and more vigorous than those of Lot 1. Detailed analysis of blood samples collected during the test are given in Appendix Table V.

Table IX.—Growth of Heifers, Wilburton.
(pounds)

Lot number Phosphorus level[1]	1 Low	2 Medium	3 High
Average weight per head			
1-31-47	382	382	382
4-27-47	430	424	441
9-28-47	548	546	613
4-16-48	595	653	717
10-31-48	758	865	923
Average gain per head			
Winter (4-27-47)	48	42	59
Summer (9-27-47)	118	122	172
Winter (4-16-48)	47	107	104
Summer (10-31-48)	163	212	206
Total gain per head			
(1-31-47 to 10-31-48)	376	483	541
Differences in gain compared to Lot 1		107	165

[1] The consumption of dicalcium phosphate in the entire period was 7.6 and 25.6 pounds for the heifers fed the medium and high levels of phosphorus, respectively.

Table X.—Average Weights of Cows, Wilburton, 1947-50.
(pounds)

Date	Weights compared	Lot 1 Low P	Lot 2 Med P	Lot 3 High P
1-31-47	Initial	654	654	654
11-22-47	End of summer[1]	693	736	685
1-30-48	Prior to calving[2]	709	770	731
10-31-48	End of summer	715	871	873
10-31-48	End of summer[3]	736	860	904
2-7-49	Prior to calving	751	884	908
10-31-49	End of summer	738	898	880
1-30-50	Prior to calving	798	953	971
10-16-50	End of summer	821	893	856

[1] End of summer grazing period. This weight was also the beginning of the winter feeding period except in 1948.

[2] Last weight obtained before any calves were born.

[3] Additional cows were placed in each lot at the beginning of the winter feeding period in October, 1948. The cows added were those from the respective lots fed three levels of phosphorus during the growth study summarized in Table IX.

Weights and condition of cows

The cows in all lots gained weight during the first two years of the experiment (Table X and Appendix Table VI). Those in Lot 1 continued to make some gains and at the end of the fourth year weighed 821 pounds; those in Lot 2, which made the greatest gains, weighed 893 pounds, and those in Lot 3 weighed 856 pounds. Despite some loss of weight among the cows of Lot 3 during the last two years of the test, these final weights indicate that phosphorus supplementation was of value in the production of heavier mature cows. In any comparison of these results with those obtained at Stillwater, however, it should be

emphasized that the initial weight of the Wilburton cows was only 654 pounds. The initial weight of the cows at Stillwater was 820 pounds.

The cows of Lot 2 consumed 23.8 gm of dicalcium phosphate per head daily during the winter and approximately 2.8 gm per head daily during the summer. Those of Lot 3 consumed 60.1 and about 7.9 gm per head daily during the winter and summer, respectively.

The lactating cows of all lots at Wilburton were never in as good condition or as thrifty in appearance as lactating cows managed similarly in most other areas of the state. Apparently factors other than level of phosphorus intake contributed to their condition and performance. The cows not suckling calves during the summer gained weight and were fleshy and thrifty in appearance.

At one time or another cows of all lots chewed on bones, wire, and other foreign material. During the summer and fall of 1949, two cows of Lot 1 and one cow of Lot 2 died. Post mortem examination showed that death was caused by foreign bodies passing through the stomach and piercing some vital organ. Death of one cow of Lot 1 in 1950 was caused by a wire staple which passed through the stomach wall into the heart. In each case, the reticulum contained such things as wire, shotgun shells, tin cans, rocks, nails, and other foreign material.

Calving data

The calving data in Table XI (also Appendix Table VII) show that only 39 calves were born in Lot 1, 34 in Lot 2, and 45 in Lot 3.

Table XI.—Summary of Calving Data, Wilburton, 1947-50.

Items compared	Lot 1 Low P	Lot 2 Med P	Lot 3 High P
Number of cows	56	46[1]	56
Number of calves born[2]	39	34	45
Number of calves weaned[3]	34	26	39
Average birth date of calves, March	10	9	18
Average birth weight of calves, lbs.[4]	68	67	72
Average weaning weight of calves, lbs.[5]	318	332	352

[1] In 1948, considerable difficulty was experienced with death losses at time of calving or shortly thereafter. These losses were not confined to any one lot. A part of the difficulty was traced to an outbreak of brucellosis in the herd, which was most serious in the cows of Lot 2. Six of the cows of this lot reacted to the brucellosis test and were slaughtered.

[2] Not all of the cows were pregnant when the experiment started. There was some variation in number of cows pregnant per lot; thus, all of the difference in number of calves born was not due to the experimental ration.

[3] The number of calves weaned when expressed as a percentage of the number of cows was 61, 56, and 70 percent for Lots 1, 2, and 3, respectively.

[4] Corrected for sex.

[5] Corrected for sex and age.

These small numbers relative to the number of cows in the test can be explained in part by the fact that only 21 of the initial 30 cows in the test were pregnant when the experiment started. Also, there was an outbreak of brusellosis in the herd. Thus, not all of the poor reproductive performance was due to phosphorus nutrition. An average of 83 percent of the calves born in all lots were weaned.

The weaning weights of all lots of calves were considered suboptimum in each year. The average weights, which were directly related to the amount of supplemental phosphorus provided, were 318 pounds for Lot 1, 332 pounds for Lot 2 and 352 pounds for Lot 3. Since the experiment was started just prior to time of calving it is probable that the supplemental phosphorus had affected birth and weaning weights only during the last 3 years of the experiment. Average birth weights of calves were 68 pounds for Lot 1, 67 pounds for Lot 2 and 72 pounds for Lot 3.

At the conclusion of the experiment, 57 cows, including a few from other experiments at Wilburton, were examined for pregnancy. Thirty-one of these were found to be open and were slaughtered by a meat packing company. There was no evidence of unusual parasitic infection in the digestive tract or of infection or other abnormalities in the reproductive tract. In nine of the cows there was evidence of penetrations of foreign material from the reticulum into the peritoneal cavity ("Hardware disease").

Blood plasma phosphorus levels

A summary of the blood plasma phosphorus values is given in Table XII. Initially, these values for the cows in all lots were the same. During the winters of 1948, 1949 and 1950, the average values for the cows of Lot 1 were consistently below 3 mg per 100 ml of plasma. Although they increased to about 3.3 mg during the grazing season, values below 3 mg extending over a long period are believed to be critical and positive evidence of phosphorus deficiency. The plasma

Table XII.—Average Plasma Phosphorus of Cows, Wilburton[1].
(mg/100 ml)

Lot Number	Phosphorus level	December	February	April	June	August	October
1	Low	2.7	2.3	2.6	3.4	3.3	3.3
2	Medium	5.9	5.5	5.3	4.4	3.8	3.5
3	High	7.3	6.2	6.7	3.6	3.7	3.8

December averages are for two years. All others are for three years.

phosphorus values of the cows of Lots 2 and 3 were directly related to phosphorus intake and were lower during the summer grazing periods when the phosphorus supplement was offered free choice than during the winter periods when it was added to the protein supplement. During the summer, only small amounts of mineral supplement were consumed by these lots; and, plasma values ranged from 3.5 to 4.4. During the winter these values increased to about 5.5 for Lot 2 and 6.5 for Lot 3. The results provide further evidence of the advantage of supplying supplemental phosphorus in the feed. Detailed results of determinations of various blood components are given in Appendix Table VIII.

Minimum phosphorus requirement

The minimum phosphorus requirement for cows at this location could not be clearly demonstrated since the performance of all cows that produced calves was considered sub-optimum regardless of their phosphorus intake. The cows of Lot 1 consumed 6.8 gm of phosphorus per head daily during winter, an estimated 9.2 gm during early summer and 4.9 gm during late summer. The plasma phosphorus values of these cows were seldom above 3 mg per 100 ml during the winter feeding period and dropped to less than 2 mg per 100 ml for a period of five months during one winter. The cows of Lots 2 and 3 consumed 11.6 gm phosphorus per head daily during the winter and those of Lot 3 consumed 18.1 gm. The average plasma phosphorus values of the cows in these two groups seldom dropped below 3 mg. Their performance as judged by appearance, weight, gain, and calving records was similar and, in general, better than that of the cows in Lot 1. Evidently at this location the minimum phosphorus requirement of cows during the winter is above 7 gm daily and may be as high as 12 gm.

Summary

The following interpretation of the results of this study is based upon the performance of range beef cattle consuming known amounts of phosphorus during the winter and estimated amounts during the summer. The estimated amounts in summer are based on an assumed intake of grass and a measured amount of mineral supplement offered free choice in salt boxes. Phosphorus intake during the summer could not be accurately determined because of selective grazing, changes in composition of grass, and variable feed consumption.

Stillwater

In north central Oklahoma (Stillwater) beef cattle grazing native grass during the summer and fed locally grown native grass hay supplemented with corn gluten meal during the winter received some slight benefit from a mineral phosphorus supplement as measured by the combined effect on growth of heifers, weight changes of cows, reproductive performance, and plasma phosphorus values. The results indicate that for cows handled in the manner described in this experiment a total daily phosphorus intake of 7 gm per head in winter and an estimated 9 gm in early summer and 6 gm during late summer is close to the minimum requirement for growth, reproduction, and lactation. This minimum requirement of phosphorus can be met during the winter by 16-20 pounds of average quality prairie hay and 1.25 pounds of a protein supplement. Native grass containing 0.1 to 0.15 percent phosphorus will meet this requirement during the summer. In practice, however, a mineral phosphorus supplement should be made available to provide a margin of safety during years of poor growth of grass. Likewise, when cows are wintered on dead range grass and fed 2 pounds of a protein supplement per head daily, additional phosphorus should be provided by means of mineral supplements such as dicalcium phosphate, steamed bone meal, or defluorinated rock phosphate. A satisfactory mineral supplement is a mixture of two parts ground rock salt and one part steamed bone meal or other phosphorus-containing supplement.

Wilburton

In southeastern Oklahoma (Wilburton), a mineral phosphorus supplement was definitely beneficial for growth of calves and heifers. Its value for cows could not be clearly demonstrated on a quantitative basis since the performance of all cows that produced calves was considered sub-optimum regardless of their phosphorus intake. Other factors peculiar to the Wilburton area that may have influenced the performance of the cows are under investigation.

Phosphorus supplementation effectively increased the phosphorus content of the blood plasma of cows, particularly during the winter, and promoted the growth of their calves. It also increased the weight of the cows. The combined results indicated that at this area the minimum phosphorus requirement was over 7 gm per head per day and might possibly be as high as 12 gm. Since the grass and forage was not a dependable source of phosphorus, it is recommended that cattle in the Wilburton area be supplied with a mineral phosphorus supplement at all times.

Appendix

The following appendix of tables gives detailed data on performance of the cows at each area, and the seasonal change in certain blood constituents of the cows and heifers at each area.

A survey of vegetation at the Wilburton area was made August, 1947 by W. C. Elder, Department of Agronomy and Harry M. Elwell, Soil Conservationist, Agricultural Research Service. Soil samples from the area were analyzed by M. J. Plice, formerly of the Agronomy Department. Complete reports of those phases of the investigation are on file in the Department of Animal Husbandry.

Appendix Table I.—Blood Constituents of Heifers, Stillwater.

Date bled	Phosphorus (mg/100 ml)			Calcium (mg/100 ml)			Carotene (mcg/100 ml)			Hemoglobin (gm/100 ml)			Red Blood Cells (million/cmm)		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1947															
February 11	5.9	6.3	6.6	11.0	11.4	11.3	78	81	82						
April 7	4.7	6.6	7.3	10.5	10.2	9.7	164	192	173						
October 7	6.0	6.1	6.0	11.8	11.8	11.9	299	264	238	8.7	8.3	8.8	5.5	5.2	5.7
November 4	5.0	5.2	5.2	11.3	11.5	11.4	251	261	319	9.5	9.4	9.3	5.3	5.1	5.1
1948															
February 12	3.5	4.9	6.4	10.9	10.8	10.2	55	58	62	10.0	9.8	9.9	6.9	6.8	6.8
March 18	3.9	6.3	7.4	11.3	11.3	11.0	54	64	51	9.7	9.6	10.0	6.2	6.1	6.3
April 22	3.9	5.8	7.0	12.5	10.8	9.9	277	263	293	10.0	9.8	9.4	6.5	6.2	6.0
June 9	6.0	5.5	5.4	10.6	10.5	11.0	668	734	693	9.7	9.8	9.6	6.0	6.1	6.0
August 19	5.3	5.3	5.2	10.9	10.4	10.5	850	671	719						
October 27	5.0	5.2	5.1				364	376	259						

Appendix Table II.—Average Weights of Cows, Stillwater.
(pounds)

	Lot 1 Low Phosphorus	Lot 2 Med. Phosphorus	Lot 3 High Phosphorus
		1947	
Average weight per cow			
January 31, 1947[1]	821	820	820
April 24, 1947	655	657	667
November 3, 1947	848	826	857
Change during winter	—166	—163	—153
Gain during summer	193	169	190
Yearly gain	27	6	37
		1948	
Average weight per cow			
November 3, 1947	848	826	857
February 10, 1948[1]	875	848	865
April 21, 1948	704	727	722
October 27, 1948	1014	953	1003
Gain to calving[2]	27	22	8
Change during winter	—134	— 99	—135
Gain during summer	310	236	281
Yearly gain	166	127	146
		1949[3]	
Average weight per cow			
October 27, 1948	987	961	991
February 15, 1949[1]	938	924	954
April 15, 1949	812	810	800
October 24, 1949	1021	1001	1014
Change to calving[2]	— 49	— 37	— 37
Change during winter	—175	—151	—191
Gain during summer	209	191	214
Yearly gain	34	40	23
		1950	
Average weight per cow			
October 24, 1949	1021	1001	1014
January 31, 1950[1]	1039	998	995
April 20, 1950	816	788	821
October 10, 1950	1094	1053	1081
Change to calving[2]	18	— 3	— 19
Change during winter	—205	—213	—193
Gain during summer	278	265	260
Yearly gain	73	52	67

[1] Last weight obtained before any calves were born.
[2] Weight gain from beginning of winter feeding period until last weight prior to calving.
[3] In the fall of 1949 heifers which had been fed various levels of phosphorus since January 1947 were added in their respective lots.

Appendix Table III.—Summary of Calving Data, Stillwater.

	Lot 1 Low Phosphorus	Lot 2 Med. Phosphorus	Lot 3 High Phosphorus
		1947	
Number of cows	10	10	10
Number of calves born	10	10	10
Number of calves weaned	10	9	10
Average birth date	April 3	March 20	March 27
Average birth weight (lbs.)	70	75	68
Average weaning weight (lbs.)	384	406	373
		1948	
Number of cows	10	10	10
Number of calves born	8	8	7
Number of calves weaned	7	8	7
Average birth date	March 29	April 9	March 31
Average birth weight (lbs.)	68	69	67
Average weaning weight (lbs.)	456	442	457
		1949[1]	
Number of cows	20	20	20
Number of calves born	19	19	18
Number of calves weaned	17	18	17
Average birth date	March 8	March 17	March 2
Average birth weight (lbs.)	77	75	76
Average weaning weight (lbs.)	440	417	428
		1950	
Number of cows	21	23	23
Number of calves born	19	21	20
Number of calves weaned	16	21	19
Average birth date	Feb. 28	March 13	March 12
Average birth weight (lbs.)	74	74	76
Average weaning weight (lbs.)	489	463	472

[1] In the fall of 1949 heifers which had been fed various levels of phosphorus since January 1947 were added in their respective lots.

Appendix Table IV.—Blood Constituents of Cows, Stillwater.

Date bled	Phosphorus (mg/100 ml)			Calcium (mg/100 ml)			Carotene (mcg/100 ml)			Vitamin A (mg/100 ml)		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1947												
February 11	4.2	6.1	7.6	11.2	11.1	11.1	91	100	122	---	---	---
April 7	6.2	7.3	8.1	9.8	9.4	9.6	261	196	198	---	---	---
June 2	4.1	4.2	4.2	11.6	11.8	11.2	1021	819	956	---	---	---
October 7	5.5	4.5	4.6	11.8	11.6	11.7	281	318	326	---	---	---
November 4	3.3	5.0	6.7	11.0	11.1	10.7	214	300	284	---	---	---
1948												
February 2	2.2	4.4	6.1	11.2	10.9	11.0	77	72	68	---	---	---
March 18	2.8	5.8	5.9	10.9	11.2	11.7	74	85	75	5.0	10.8	4.7
April 22	3.4	6.3	5.4	10.5	10.4	11.3	278	284	339	11.4	4.8	7.5
June 9	4.3	4.7	4.6	9.9	10.2	10.6	746	781	866	---	---	---
August 19	5.1	4.9	5.0	10.9	10.6	10.7	841	701	738	33.7	29.7	24.5
October 27	4.4	5.6	5.4				357	380	348	27.0	29.2	34.3
1949												
December 20 (1948)	6.0	7.0	7.5	---	---	---	141	131	93	17.4	16.0	20.4
February 15	3.6	5.4	6.7	---	---	---	155	118	104	16.4	16.4	14.0
April 5	3.1	5.2	6.4	---	---	---	238	171	144	13.1	10.0	15.2
June 15	5.0	4.4	4.9	---	---	---	976	833	857	15.4	16.1	17.3
August 11	7.4	6.0	6.4	---	---	---	487	470	441	---	---	---
September 8	4.6	3.9	4.5	---	---	---	662	558	486	30.1	28.8	26.2
October 25	3.6	3.8	3.6	---	---	---	675	524	528	20.6	28.4	22.9
1950												
January 9	4.6	5.7	5.1	---	---	---	136	151	159	23.9	21.0	21.0
March 2	3.6	4.9	5.0	9.7	---	9.7	183	165	163	5.5	9.2	13.2
April 27	4.5	5.7	6.3	10.1	---	9.4	360	328	409	10.8	12.4	18.2
June 28	3.8	4.7	3.6	10.2	---	9.3	864	816	789	24.0	17.6	23.7
August 23	4.6	3.1	4.0	---	---	---	818	850	792	25.4	18.2	20.9
October 10	4.5	2.9	4.8	---	---	---	810	773	691	17.4	18.7	22.2

Appendix Table IV.—(Continued)

Date Bled	Hemoglobin (gm/100 ml)			Hematocrit (Vol. %)			R.B.C. (million/cmm)			Plasma Protein (mg/100 ml)		Plasma Mg (mg/100 ml)	
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 3	Lot 1	Lot 3
1947													
October 7	9.6	9.1	9.0	---	---	---	6.2	5.5	5.7	---	---	---	---
November 4	9.5	9.3	9.3	---	---	---	5.4	5.3	5.2	---	---	---	---
1948													
February 2	10.0	9.9	9.8	36.8	32.9	37.2	6.8	6.8	6.8	---	---	---	---
March 18	9.3	9.8	9.6	37.4	36.0	36.7	6.0	6.3	6.1	---	---	---	---
April 22	8.8	9.5	9.2	---	---	---	5.7	6.1	5.9	---	---	---	---
June 9	9.5	9.7	9.8	---	---	---	5.8	6.0	5.9	---	---	---	---
1950													
March 2	9.9	--	10.1	34.0	---	33.3	--	--	--	7.2	7.0	1.3	1.5
April 27	10.0	--	10.1	33.2	---	33.4	--	--	--	7.1	7.4	1.9	2.3
June 28	10.6	--	10.7	36.8	---	37.3	--	--	--	7.0	7.3	1.3	2.0
October 10	13.0	--	13.6	38.0	---	36.3	--	--	--	---	---	---	---

Appendix Table V. — Blood Constituents of Heifers, Wilburton.

Date bled	Phosphorus (mg/100 ml)			Calcium (mg/100 ml)			Carotene (mcg/100 ml)		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1947									
February 3	7.7	8.2	8.2	10.1	10.5	10.3	106	98	91
April 27	5.4	7.0	8.6	10.5	10.9	10.2	274	279	310
June 27	6.9	6.3	6.3	10.6	11.5	11.1	559	380	570
August 27	4.5	4.3	5.2	11.6	11.7	11.5	380	321	337
September 28	4.3	4.3	5.3	11.6	11.5	11.5	447	422	438
November 24	3.8	3.5	3.4	11.7	11.6	11.4	706	571	555
1948									
December 31 (1947)	2.8	5.5	8.2	11.6	11.6	10.4	242	226	184
February 2	2.7	5.4	7.1	12.6	12.2	12.4	133	154	168
April 16	3.2	5.5	6.6	12.3	12.0	10.4	400	267	344
June 1	5.4	5.7	4.7	10.7	10.8	10.3	549	339	308
August 12	5.7	5.4	4.9	10.7	10.3	10.3	735	827	754

Appendix Table V.—(continued)

Date bled	Hemoglobin (gm/100 ml)			Hermotocrit (Vol. %)			Red blood cells (million/cmm)		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1947									
November 24	9.7	9.4	10.6	37.6	37.2	37.0	5.6	5.4	5.9
December 31	9.9	9.8	9.9	37.4	37.2	38.0	5.4	5.2	5.4
1948									
February 2	9.7	10.4	10.0	37.2	37.0	37.6	6.5	6.5	6.4
April 16	9.6	9.6	9.4				6.5	6.3	6.2
June 1	9.9	9.7	9.9				5.7	5.6	5.9

Appendix Table VI.—Average Weights of Cows, Wilburton. *(pounds)*

	Lot 1 Low Phosphorus	Lot 2 Med. Phosphorus	Lot 3 High Phosphorus
		1947	
Average weight per cow			
January 31, 1947[1]	654	654	654
April 27, 1947	606	605	597
November 22, 1947	693	736	685
Change during winter	— 48	— 49	— 57
Gain during summer	87	131	88
Yearly gain	39	82	31
		1948	
Average weight per cow			
November 22, 1947	693	736	685
January 30, 1948[1]	709	770	731
April 16, 1948	625	724	722
October 31, 1948	715	871	873
Gain to calving[2]	16	34	46
Change during winter	— 68	— 12	— 63
Gain during summer	90	47	151
Yearly gain	22	35	88
		1949[3]	
Average weight per cow			
October 31, 1948	736	860	904
February 7, 1949[1]	751	884	908
April 19, 1949	668	790	793
October 31, 1949	738	898	880
Gain to calving[2]	15	24	4
Change during winter	— 68	— 70	—111
Gain during summer	70	108	87
Yearly change	2	38	— 24
		1950	
Average weight per cow			
October 31, 1949	738	898	886
January 30, 1950[1]	798	953	971
April 17, 1950	723	804	789
October 16, 1950	821	893	856
Gain to calving[2]	60	55	85
Change during winter	—15	— 94	— 97
Gain during summer	98	89	67
Yearly Change	83	— 5	— 30

[1] Last weight obtained before any calves were born.

[2] Weight gain from beginning of winter feeding period until last weight prior to calving.

[3] In the fall of 1949 heifers which had been fed various levels of phosphorus since January 1947 were added in their respective lots.

Appendix Table VII.—Summary of Calving Data, Wilburton.

	Lot 1 Low Phosphorus	Lot 2 Med. Phosphorus	Lot 3 High Phosphorus
		1947	
Number of cows	10	10	10
Number of calves born[1]	8	5	8
Number of calves weaned	7	5	7
Average birth date	March 21	March 26	April 5
Average birth weight (lbs.)	62	57	56
Average weaning weight (lbs.)	331	295	314
		1948	
Number of cows	10	10	10
Number of calves born[2]	5	6	4
Number of calves weaned	5	2	3
Average birth date	March 7	February 23	March 27
Average birth weight (lbs.)	70	66	77
Average weaning weight (lbs.)	332	342	383
		1949[3]	
Number of cows	19	13	18
Number of calves born	17	13	17
Number of calves weaned	13	9	13
Average birth date	March 3	March 4	March 2
Average birth weight (lbs.)	67	68	76
Average weaning weight (lbs.)	293	352	360
		1950	
Number of cows	17	13	18
Number of calves born	9	10	16
Number of calves weaned	9	10	16
Average birth date	March 9	March 10	March 7
Average birth weight (lbs.)	71	78	77
Average weaning weight (lbs.)	315	341	350

[1] Only 21 of the cows were pregnant when the experiment started. Thus, difference in the number of calves born in 1947 were not related to phosphorus intake.

[2] Considerable difficulty was experienced with death losses at time of calving or shortly thereafter. A part of the difficulty was traced to an outbreak of brucellosis in the herd. Six of the cows in Lot 2 reacted to the brucellosis test and were slaughtered.

[3] In the fall of 1949 heifers which had been fed the various levels of phosphate since January 1947 were added in their respective lots.

Appendix Table VIII.—Blood Constituents of Cows, Wilburton.

Date bled	Phosphorus (mg/100 ml)			Calcium (mg/100 ml)			Carotene (mcg/100 ml)			Vitamin A (mg/100 ml)		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1947												
February 3	7.1	7.1	7.1	10.3	10.4	10.7	128	112	105	---	---	---
April 27	4.8	6.2	6.6	10.5	10.4	10.4	316	258	301	---	---	---
June 27	4.5	4.5	4.1	11.6	10.6	10.8	773	718	651	---	---	---
August 27	3.4	3.5	3.8	11.5	10.6	10.6	450	433	383	---	---	---
September 28	2.4	2.5	2.9	11.9	11.3	11.8	455	395	449	---	---	---
November 24	2.5	2.1	2.6	11.8	11.1	10.8	686	534	573	---	---	---
1948												
Dec. 31 (1947)	1.9	5.4	7.4	11.8	11.7	10.1	242	214	179	---	---	---
February 2	1.8	5.0	5.9	12.3	11.6	11.2	186	200	182	---	---	---
April 16	1.8	5.3	6.5	11.5	11.4	10.7	427	335	351	---	---	---
June 1	3.0	4.7	4.1	11.4	10.6	10.3	679	485	441	---	---	---
August 12	3.8	4.7	4.3	10.8	10.1	10.8	811	787	708	---	---	---
November 11	3.3	4.3	4.7	---	---	---	274	251	226	22.3	19.1	---
1949												
January 11	2.6	6.6	7.4	---	---	---	142	128	104	18.2	22.4	17.7
February 7	2.5	6.1	6.3	---	---	---	151	180	150	9.6	15.0	10.1
April 19	2.8	4.9	7.7	---	---	---	230	271	194	12.3	13.0	9.2
June 24	3.0	5.0	3.5	---	---	---	776	869	714	26.8	24.4	27.4
August 26	3.0	3.3	3.7	---	---	---	493	628	494	23.3	31.1	20.3
October 31	3.0	3.0	3.0	---	---	---	689	721	618	16.6	17.6	16.7
1950												
January 2	3.5	5.8	7.1	---	---	---	212	232	185	17.9	20.9	20.3
February 23	2.7	5.4	6.3	11.0	---	9.3	158	130	159	10.4	12.6	9.8
April 27	3.1	5.6	6.0	10.6	---	9.5	266	137	182	15.1	13.9	9.0
June 19	4.2	3.5	3.3	12.0	---	11.6	909	1102	896	19.8	18.9	20.0
August 16	3.0	3.4	3.2	---	---	---	710	881	717	43.8	39.0	42.8
October 16	3.6	3.1	3.8	---	---	---	---	---	---	---	---	---

Appendix Table VIII.—(continued)

Date bled	Hemoglobin (gm/100 ml)			Hematocrit (Vol. %)			R.B.C. (million/cmm)			Plasma protein (mg/100 ml)		Plasma Mg (mg/100 ml)	
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 3	Lot 1	Lot 3
1947													
November 24	9.8	9.7	9.8	36.6	36.8	36.7	5.1	5.3	5.3	---	---	---	---
December 31	10.0	10.0	9.9	36.5	36.9	37.3	5.4	5.3	5.2	---	---	---	---
1948													
February 2	10.0	9.8	9.5	36.4	36.6	37.6	6.1	5.9	6.0	---	---	---	---
April 16	9.9	9.2	9.1	---	---	---	6.7	6.1	5.8	---	---	---	---
June 1	9.8	9.7	9.4	---	---	---	5.9	5.9	5.8	---	---	---	---
1950													
February 23	9.3	---	9.3	32	---	33	---	---	---	6.5	6.0	1.7	1.7
April 27	8.7	---	8.5	30	---	33	---	---	---	6.9	6.0	1.7	1.7
June 19	9.7	---	10.5	34	---	34	---	---	---	7.5	7.2	1.8	2.2