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The Performance of the Pregnant and Lactating Ewe as Affected by Phosphorus Sources and Quantity

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The Performance of the Pregnant and Lactating Ewe as Affected by Phosphorus Sources and Quantity

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THE RANGE sheep industry is one of Idaho's principal agricultural enterprises. During years of dry falls and open winters, range ewes in southern Idaho graze for a considerable time on forage low in phosphorus and other essential nutrients.(2)[4]. Observations have indicated a low percentage lamb crop among ewes grazed on the range during autumn and winter months of years of low rainfall. The greatest losses were attributed to weak lambs, stillbirths, and abortions.

REVIEW OF LITERATURE

Pearson and associates (32) state that a phosphorus deficiency may be indicated by slow growth, high feed requirement, unthrifty appearance, low inorganic blood phosphorus values, weak lambs, and decreased milk production. Morris and Ray (29) believe that the high feed requirement and slow growth of animals fed a low phosphorus ration are due to decreased protein digestibility. They believe that this is probably the result of a diminished secretion of digestive juices and enzymes caused by a lack of phosphorus, which appears to be required in their metabolic reactions. Palmer and associates (31), working with dairy animals, concluded that a ration deficient in phosphorus as well as protein delayed sexual maturity and repressed normal evidences of estrum so that periods of estrum appear to be missed but did not interfere with normal regularity of ovulation or the ease of conception. Theiler et al. (37), during a three-year study on cows on phosphorus-deficient rations and cows supplemented with phosphorus, found no significant differences in the birthweight between calves born of phosphorus-fed and phosphorus-deficient mothers. However, the calves of the phosphorus-supplemented mothers attained sexual maturity earlier than their controls and their skeletal development was superior in every way to that of their controls.

Beeson and associates (4) summarized the first year's work of this study on the effect of low phosphorus intake of pregnant ewes as follows: "The general conclusion indicated by the findings of this study is that a level of 0.14 percent of phosphorus in the diet of ewes is on the border line for maintaining a normal

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phosphorus balance in ewes during pregnancy and is not reflected in the lamb crop. This conclusion is supported by the extremely low blood prosphorus values and the thin and emaciated condition of the ewes. Expressed in other terms, an intake of 2.11 grams of phosphorus daily per 100 pounds of ewe weight is not sufficient for normal phosphorus metabolism."

Knox and Watkins (21) found that by feeding phosphorus supplements to range cattle and ewes where deficiency symptoms were not evident resulted in smaller death losses in newborn calves, larger number of calves weaned, greater weight of calves and lambs at weaning, greater gain in weight by yearling and two-year-old cattle, and higher wool production from range ewes, when compared to those fed salt as the single mineral supplement.

Duerden and associates (8) found that ewes on a phosphorus deficient ration produce a lighter fleece, shorter in length, and of finer fiber quality than sheep fed a high phosphorus ration.

Beeson and associates (3), working with lambs, found an increase in the feed efficiency of 15.8 percent after adding enough bone meal to a ration containing 0.10 percent phosphorus to bring its phosphorus content up to 0.13 percent.

Eckles and Gullickson (12), working with dairy cows, found that cows on a low phosphorus ration required at least 20 percent more digestible nutrients to maintain their live weight than was indicated by Morrison's (28) feeding standard.

Kleiber and associates (20), working with beef heifers, found that phosphorus deficiency lowers the total efficiency of energy utilization mainly by lowering the appetite. Otto (30), working with sheep, found that food consumption increases with the addition of phosphatic supplements to phosphorus-deficient rations, and that the phosphorus deficiency is invariably associated with poor appetite.

Theiler et al. (37) concluded that animals given sufficient phosphorus utilize their food better and gain more per unit of food consumed than do animals on a low phosphorus diet.

Lofgreen and Kleiber (23), feeding chopped alfalfa hay to wether lambs in metabolism trials, found that the true digestibility of the phosphorus in the hay was 91 percent, indicating that the phosphorus in the hay was highly available for absorption by lambs.

Beeson and associates (3) found that an organic source of phosphorus, found in cottonseed meal, was not as available to lambs as the inorganic phosphorus in bone meal, but it appears that the source of the protein in the rations may have contributed more to the difference than did the phosphorus.

Hart and associates (16) believe that there may be a dietary factor other than vitamin D which assists in the transport of calcium and possibly also phosphorus through the intestinal wall.

Gallup and Briggs (14), working with young growing wether lambs, found phosphorus balances all to be negative with rations supplying 1.4 to 1.7 grams phosphorus, about equally positive and negative with rations supplying 1.9 to 2.1 grams phosphorus, and all positive with those supplying 2.4 to 2.9 grams daily per 100 pounds live weight respectively. The calcium requirements appeared to be slightly greater than the phosphorus requirement. DuToit and associates (9) found that a pasture must furnish 1.5 grams of phosphorus for a 100 pound ewe per day or contain approximately 0.14 percent phosphorus on the air-dry basis. Mitchell (26) states that when roughage contains about 0.12 percent or less phosphorus on air-dry basis, the roughage will not provide adequate phosphorus for the animal. He further states that a young growing lamb requires 0.15 percent phosphorus in the dry ration. Fraps (13) concluded from mineral balance studies that a daily intake of .74 gram of phosphorus met the maintenance requirements of a dry ewe weighing 100 pounds.

Concerning the calcium to phosphorus ratio, Beeson et al. (1) have shown that ewes reproduce normally when fed alfalfa hay containing 0.16 percent phosphorus and 1.5 percent calcium. Since this results in a calcium : phosphorus ratio of approximately 9.4 to 1, it may be assumed that a calcium : phosphorus ratio as wide as 9.4 to 1 is satisfactory for sheep where the ration is adequately supplied with calcium, phosphorus, and vitamin D.

Hart and associates (17) have shown that variations in the calcium : phosphorus ratio from 1 : 1 to 39 : 1 occur in range forage. In the latter case (dry leached broadleaf alfilaria) the percentage content of calcium was 1.17 and phosphorus 0.03. Their data show a variation in the calcium content of range grasses from 0.10 to 2.90 and a variation in the phosphorus content from 0.03 to 0.68 percent. The extreme ratios were found only late in the season.

DuToit and associates (11) found that a change in the dietary phosphorus is rapidly reflected by a changing level in the inorganic phosphorus of the blood, while the calcium content of the blood is not rapidly reflected in spite of the fact that the ratios between calcium and phosphorus in the rations of the groups were 10.5 to 1, 1.65 to 1, and 0.55 to 1 respectively — a twenty-fold variation. They conclude that it is unlikely that a marked change in the calcium content of the blood can be brought about by varying the calcium of the diet. Johnson (19) reported approximately the same blood values of inorganic phosphorus for lactating and dry cows, a value of 4.33 mg. per 100 ml. of blood. Becker and associates (6) gave values of 2.87 mg. for nursing cows and 3.80 mg. for dry cows. Samples were taken from cows pastured in phosphorus-deficient areas. Saarinen (33) reported a slight correlation between inorganic blood phosphorus and milk yield. Greaves and associates (15) found a close cor-

relation between phosphorus intake and the inorganic phosphorus of the blood.

Concerning the availability of phosphorus, Theiler et al. (36) in his review, says, "A good deal probably depends upon the bases magnesium oxide and calcium oxide associated with it, and upon the plane of intake. The percentage utilization is greater in young grasses than old, although even in old grasses it may be high in spite of association with excess calcium and magnesium it would appear that the lower the actual amount of phosphorus the higher is the percentage utilization." Theiler et al. (37) also state further that the ratio between calcium and phosphorus is probably not so important as is the presence of adequate calcium, phosphorus, and vitamin D present in the ration.

In an uncontrolled study, Holm and Bolin (18) attributed range ewe abortions and stillbirths occurring in southern Idaho to a phosphorus deficiency. DuToit and associates (9) found no effects on reproduction after feeding several groups of sheep rations furnishing from 0.47 to 2.92 grams of phosphorus daily. Hart et al. (17) found that a low calf crop of cows that grazed pastures and soils low in the content of phosphorus and calcium was not due to abortion but to a failure to conceive.

In summarizing, the type of symptom caused by a phosphorus deficiency will depend upon the extent and length of time of the deficiency; and an extreme deficiency or a complete lack of phosphorus in the ration causes marked emaciation, stiffness of joints, loss of appetite, depraved appetite, decreased milk flow and failure to conceive (22), (24), (25), (32), (30). In a search of the literature pertaining to a phosphorus deficiency, the authors have not found any evidence to indicate that such a deficiency during gestation produces abortions or stillbirths. Limited experimental information is available on the effect of the phosphorus intake level and the blood phosphorus content for the development of the lamb during pregnancy. A summary of the suggested minimum requirements of phosphorus for the various classes of sheep is shown in Table 1.

PURPOSE OF THE STUDY

The object of this experiment was to determine the effect of a deficiency of phosphorus in the ewe's ration during gestation and lactation on the birthweight of lambs, percent lamb crop, weaning weight of lambs, milk production, and wool production.

EXPERIMENTAL PROCEDURE

The experiment was begun in the fall of 1942 and carried through 1951. One hundred and ninety-five crossbred, white-faced yearling ewes were selected and divided into groups of 65 each and kept at the Branch Experiment Station, Caldwell, during the entire year. One lot was placed on a low phosphorus ration and is designated Lot I, another lot was fed bone meal in addition to the low phosphorus ration fed to Lot I and is desig-

nated Lot II, while the third lot was placed upon an alfalfa hay ration and is designated Lot III. The experimental rations were fed from the end of the breeding season in the fall, which usually was between October 3 and 15, until grass was available in the spring, usually about the middle of April. This covered the period during pregnancy and lactation, after which the ewes were all put into one band and grazed together during the late spring, summer, and early fall on irrigated pastures and aftermath crops.

The procedure of grazing the ewes on pasture during the summer and placing them on the experimental rations during the winter was designed to obtain the objective outlined for the experiment. Since the objective was that of studying the effect

Table 1. - Phosphorus requirement for ewes. Adapted in part for Beeson, (1)

Phosphorus Level in ration	Condition of ewe	Percent in ration	Reference
Deficient level	Dry ewes[1]	0.11	Beeson, W. M., et al. (5)
Borderline level	" "	0.14	Estimated
Adequate level	" "	0.16	Beeson, W. M., et al. (5)
Deficient level	Pregnant ewe	0.11	Beeson, W. M., et al. (5)
" "	" "	0.11	DuToit, et al., (10), (11)
Borderline level	" "	0.14	Estimated
Adequate level	" "	0.16	Beeson, W. M., et al. (5)
" "	" "	0.18	Mitchell, H. H. and F. J. McClure (27)
" "	" "	0.21	DuToit, et al., (10), (11)
" "	" "[3]	0.16	Pearson, et al., (1949)[2]
" "	" "[4]	0.18	Pearson, et al., (1949)[2]
Deficient level	Lactating ewe	0.11	Beeson, W. M., et al. (5)
" "	" "	0.11	DuToit, et al., (9), (11)
		0.16-	
Borderline level	" "	0.18	Estimated
Adequate level	" "	0.21	Beeson, W. M., et al. (5)
" "	" "	0.21	DuToit, et al., (10), (11)
" "	" "	0.19	Mitchell, H. H. and F. J. McClure (27)
" "	" "	0.22	Pearson, et al., (1949)[2]

[1] Refers to the period between weaning lambs and breeding.
[2] Not part of the original table but added for comparison; from data prepared by P. B. Pearson and associates.[32]
[3] First 100 days of gestation.
[4] Last six weeks before lambing.

of a low phosphorus intake on the mortality of the lambs born, it was necessary to use the system of depriving the ewe of this nutrient at the end of the breeding season in order to avoid a low conception percentage of the ewes.

The ewes were weighed individually at the start of the wintering period and again after lambing. An individual record of the wool clip was also kept.

The lambs were weighed individually and ear-tagged at birth in order to be able to identify the production of each ewe. The lambs were again weighed individually before going on pasture and at weaning.

Blood samples were taken at varying intervals from ewes during the pregnancy and lactating periods. Samples usually were taken from 10 ewes during the early part of pregnancy, at approximately the middle of pregnancy, and just prior to lamb-

ing. Samples were taken on more than 10 ewes and more than three times during the pregnancy and lactation periods the year 1942-43 and 1950-51.

The samples obtained gave inorganic blood phosphorus values for varying periods of time before and after parturition. Since the ewes could not lamb on the same date and since it was not convenient to take samples every day, the time interval between sampling and lambing is not the same for every ewe. A total of 1024 samples of blood was collected from ewes of the three lots during the time of the study.

Experimental Rations

Data relating to the experimental rations are presented in Tables 2, 3, 4, and 5.

The phosphorus content of the feeds used was determined

Table 2. - Average daily feed consumption of ewes by lots and by years during the wintering period.

	Alfalfa chaff	Clover chaff	Ground barley	Wet beet pulp	Blood meal	Alfalfa hay	Bean straw	Dried beet pulp molasses	Salt	Bone meal
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1942 - 43										
Lot I	4.25	2.33							.026	
Lot II	4.12	2.56							.007	.013
Lot III						3.80			.019	
1943 - 44										
Lot I						4.23			.032	
Lot II						4.43			.015	.007
Lot III						4.26			.030	
1944 - 45										
Lot I						1.53	1.79	1.00	.027	
Lot II						1.50	1.85	1.00	.026	.009
Lot III						3.73			.028	
1945 - 46										
Lot I						1.88	1.74	1.00	.024	
Lot II						2.21	1.67	1.00	.024	0.160
Lot III						4.21			.022	
1946 - 47										
Lot I				7.24	.080	.75		1.88	.053	
Lot II				7.80	.070	.75		1.82	.044	.025
Lot III						4.15			.032	
1947 - 48										
Lot I				6.09	.080	.81		2.04	.047	
Lot II				7.05	.080	.81		2.04	.041	.025
Lot III						3.65			.035	
1948 - 49										
Lot I				7.40	.076	.76		1.90	.047	
Lot II				7.23	.078	.73		1.89	.045	.025
Lot III						4.39			.019	
1949 - 50										
Lot I				9.61	.056	.81		1.39	.040	
Lot II				10.39	.061	.83		1.46	.040	.022
Lot III			*.40			3.54			.014	
1950 - 51										
Lot 1				9.60	.061	.606		1.52	.036	
Lot II				11.01	.060	.601		1.50	.035	.018
Lot III			**.28			5.03			.019	

* 4,450 lb. barley fed Feb. 1 to May 1, 1950
**3,150 lb. barley fed Jan. 30 to May 1, 1951

by direct analysis except as indicated in Table 3. For these feeds, the phosphorus content given by Morrison (28) was used.

The digestible protein and total digestible nutrients were calculated from Morrison (28) and are presented in Table 4. The digestible protein and the total digestible nutrients meet the

Table 3. - Phosphorus content of feeds, percent

Year	Barley	Wet beet pulp	Alfalfa Hay 1st cut	2nd cut	3rd cut	Clover chaff	Alfalfa chaff	Molasses dried beet pulp	Bone meal	Blood meal	Bean straw	Oats***
1942-43	.25			.20		.10	.13		15.40			
1943-44	.35		.16	.22					14.67			
1944-45	.39		.17	.22	.17			.07	13.80		.14	.37
1945-46			.19	.22				.084	14.85		.20	
1946-47	.40	.01	.19*					.084	13.20	.27		
1947-48**		.01	.20*					.09	14.00	.25		
1948-49	.40	.01	.18*					.09	13.80	.25		
1949-50**	.40	.01	.20*					.09	14.00	.25		
1950-51**	.40	.01	.20*					.09	14.00	.25		

* Cutting not specified. Same hay fed all Lots.
** No analysis; phosphorus content estimated from Morrison,[28].
***Creep fed to lambs.

Table 4. - Average digestible protein and total digestible nutrients in the ration for each ewe during gestation

Year	Lot I		Lot II		Lot III	
	Digestible protein	Total digestible nutrients	Digestible protein	Total digestible nutrients	Digestible protein	Total digestible nutrients
	lb.	lb.	lb.	lb.	lb.	lb.
1943	0.19	1.81	0.18	1.76	0.40	1.91
1944	0.44	2.13	0.46	2.23	0.45	2.14
1945	0.24	2.30	0.24	2.31	0.39	1.88
1946	0.28	2.45	0.31	2.59	0.44	2.12
1947	0.32	2.42	0.31	2.41	0.44	2.09
1948	0.33	2.46	0.33	2.55	0.38	1.84
1949	0.32	2.45	0.32	2.41	0.49	2.21
1950	0.29	2.29	0.31	2.42	0.37	1.78
1951	0.28	2.28	0.29	2.39	0.57	2.53

requirements for gestating ewes as set forth by the National Research Council (32) except for the 1942-43 period, when the protein levels were low during the last 6 weeks of gestation. Since the alfalfa chaff was not very palatable there may have been some unrecorded waste which would also help account for the fact that the ewes in both Lots I and II did poorly during the 1942-43 period. For the remainder of the experiment the rations were palatable and contained sufficient protein and total digestible nutrients.

In Table 5 the data presented show the percentage phosphorus content of the ration, and the grams phosphorus consumed per ewe per day.

The feeds for the experimental rations were selected to develop a low phosphorus intake. Bone meal was used to increase the phosphorus content of the deficient ration. Alfalfa hay was used as a check ration and to represent the common method of winter feeding.

The rations for the 1942-43 period were alfalfa and clover

chaff containing 0.11 phosphorus for Lots I and II with Lot II being supplemented with enough bone meal to bring the phosphorus content of the ration to 0.17 percent. Lot III received alfalfa hay.

During the period of 1943-44, a ration of alfalfa hay containing 0.16 percent phosphorus was fed to Lots I and II with Lot II being supplemented with enough bone meal to bring the phosphorus content of their ration to 0.18 percent. Lot III was fed 0.22 percent phosphorus alfalfa hay.

During the period of 1944-45 and 1945-46, Lots I and II were fed a ration made up of alfalfa hay, bean straw, and molasses dried beet pulp while Lot III received 0.19 percent phosphorus alfalfa hay during 1944-45 and 0.20 percent phosphorus alfalfa hay during 1945-46. The phosphorus content of the ration for Lot I during 1944-45 was 0.14 percent while during 1945-46 the

Table 5. - Average phosphorus content of ewe rations during gestation and lactation*

	Lot I		Lot II		Lot III	
	Percent	Grams per ewe per day	Percent	Grams per ewe per day	Percent	Grams per ewe per day
1943	.11	2.45	.17	3.28	.20	3.45
1944	.16	3.02	.18	3.69	.22	4.02
1945	.14	2.71	.16	3.21	.19	3.26
1946	.18	3.81	.23	5.51	.20	3.80
1947	.11	1.79	.18	2.93	.19	3.58
1948	.12	1.99	.19	3.26	.20	3.31
1949	.11	1.81	.20	3.24	.18	3.59
1950	.12	1.85	.20	3.27	.18	3.21
1951	.11	1.67	.18	2.84	.20	4.57

* All wet beet pulp was converted to dry basis.

phosphorus content was 0.18 percent due to the high phosphorus content of the bean straw that year. The phosphorus content of the ration fed Lot II was 0.16 percent during 1944-45 and 0.23 percent during 1945-46.

During the wintering periods from 1946 to the conclusion of the study in 1951 a ration of wet beet pulp, blood meal, alfalfa hay and molasses dried beet pulp was fed Lots I and II, Lot II being supplemented with bone meal. Lot III continued on a ration of alfalfa hay. The percent phosphorus in the ration as well as the daily phosphorus consumption is shown in Table 5. The average daily feed consumption of each ewe by lot by year is given in Table 2.

EXPERIMENTAL RESULTS

Lamb Production

Data relating to the effect of the level of phosphorus intake on the development of the lamb *in utero* and during the period of lactation are presented in Tables 6, 7, 8, 9, and 10. The percentages of ewes lambing based on ewes bred were not greatly different among the three rations for the various years. The total average percentage of ewes lambing for all years, was 93

for the group fed the low phosphorus ration, 94 for the group fed the low phosphorus plus bone meal, and 95 for the alfalfa fed group.

Those ewes fed the low phosphorus ration produced the greatest number of triplets (Table 6). The total average percentage of lambs born as twins or triplets of each group throughout the ten years of study was approximately the same: 54, 56, and 55 percent for Lots I, II, and III, respectively.

The average total percentage of live lambs born, Table 7, among the three lots was approximately the same.

The Montana Station (35) (38) (39) (40) (41) (42), reported percentages of live lambs born ranging from 95 to 132 for the years 1949 to 1952, inclusive. The number of lambs born dead in this phosphorus study, as shown in Table 10, is too small to be of any significance.

The mortality of lambs during the first 48 hours of lactation of the ewes fed the three rations (Tables 6, 9, 10, and 11),

Table 6. - Lambing percentages and mortality of each group

Year	Ewes bred	Ewes lambed	Lambs born	Pairs of twins	Triplets	Lambs on pasture*	Percent lambs born of ewes bred	Percent lambs weaned of ewes bred	Mortality 48 hours		weaning	
	No.	No.	No.	No.	No.	No.			No.	%	No.	%
						Lot I-low phosphorus						
1943	65	57	68	11		36	105	55	21	31	32	47
1944	53	49	53	4		51	100	96	2	4	2	4
1945	51	48	68	20		57	135	112	1	1	11	16
1946	48	42	61	18	1	55	127	115	5	6	6	10
1947	31	28	47	17	1	38	152	123	10	21	10	21
1948	34	34	56	14	4	40	165	118	14	25	16	28
1949	50	48	64	14	1	31	128	62	22	34	33	52
1950	60	55	76	19		70	127	117	6	8	6	8
1951	65	63	95	26	3	56	146	86	39	41	39	41
Total**	457	424	588	143	10	434	128	102	120	21	155	27
						Lot II-low phosphorus plus bone meal						
1943	65	60	65	5		45	100	69	13	20	20	31
1944	61	57	62	5		58	102	95	1	2	4	6
1945	58	54	74	20		58	128	100	4	5	15	20
1946	47	46	69	21	1	55	147	117	5	7	14	20
1947	32	29	51	20	1	45	159	141	5	10	6	12
1948	31	28	47	19		40	152	129	4	8	7	15
1949	50	45	66	17	2	56	132	112	7	11	10	15
1950	60	57	82	23	1	72	137	120	0	0	8	10
1951	65	64	102	32	3	66	157	102	35	34	35	34
Total**	469	440	618	162	8	495	132	106	74	12	119	19
						Lot III-alfalfa hay						
1943	65	63	66	3		61	102	94	5	8	5	8
1944	61	57	59	2		56	97	92	3	5	3	5
1945	58	56	82	26		65	141	112	2	2	17	21
1946	52	50	77	25	1	66	148	127	2	3	11	14
1947	36	35	56	21		52	156	144	3	5	4	7
1948	36	33	54	21		48	150	133	4	7	6	11
1949	50	50	67	17		61	134	122	5	7	6	9
1950	60	54	79	25		73	132	122	1	1	6	8
1951	65	61	92	31		77	142	118	3	3	15	16
Total**	483	459	632	171	1	559	131	116	28	4	73	12

* Date lambs placed on pasture each year

1943 - April 4
1944 - April 4
1945 - April 4
1946 - April 27
1947 - April 17
1947 - April 27
1949 - May 2
1950 - May 1
1951 - May 1

**Percentages are given as averages

Table 7. - Summary of lambing percentages

Year	No. of ewes bred	Percent of ewes lambing	Percent lambs born of ewes lambing	Percent of live lambs born of lambs born	Percent of lambs weaned of lambs born	Percent of lambs weaned of ewes bred
			Lot I Low phosphorus			
1943	65	88	119	95	53	55
1944	53	93	108	100	96	96
1945	51	94	142	98	84	112
1946	48	88	145	90	90	115
1947	31	90	168	82	81	123
1948	34	100	165	100	71	118
1949	50	96	133	98	48	62
1950	60	92	138	100	92	117
1951	65	97	151	95	59	86
Averages	457*	93	138	97	74	102
			Lot II Low phosphorus plus bone meal			
1943	65	92	108	97	69	69
1944	61	93	109	100	94	95
1945	58	93	137	96	78	100
1946	47	98	150	93	80	117
1947	32	91	176	94	88	141
1948	31	90	168	100	85	129
1949	50	90	147	95	85	112
1950	60	95	144	100	88	120
1951	65	99	189	87	65	102
Averages	469*	94	140	96	80	106
			Lot III Alfalfa hay			
1943	65	97	105	98	92	94
1944	61	94	104	98	95	92
1945	58	98	146	99	79	112
1946	52	96	154	97	86	127
1947	36	97	160	96	93	144
1948	36	92	164	100	89	133
1949	50	100	134	92	91	122
1950	60	90	146	100	92	122
1951	65	94	151	97	84	118
Averages	483*	95	138	98	88	116

* Totals

Table 8. - Lamb weights, gains, and ewe production by lots and years

Year	Average birth weight	Average total gain	Average days	Average daily gain	Percent of lambs weaned of ewes lambed
	Lb.	Lb.		Lb.	
		Lot I—Low phosphorus			
1944	10.6	39.8	69	.57	104
1945	10.2	67.9	157	.45	119
1946	9.5	36.5	79	.50	131
1947	9.4	28.5	66	.44	136
1948	9.8	36.1	79	.45	118
1949	9.3	39.7	83	.48	65
1950	10.2	33.2	79	.35	127
1951	10.3	34.0	81	.36	89
Average	9.8	40.2	89	.46	108
		Lot II—Low phosphorus plus bone meal			
1944	10.5	38.4	69	.56	102
1945	10.5	66.8	155	.44	107
1946	9.7	35.4	80	.47	120
1947	9.9	29.6	68	.46	155
1948	9.3	35.6	74	.49	143
1949	9.6	36.4	84	.46	124
1950	10.2	35.8	80	.46	126
1951	9.8	33.9	80	.44	150
Average	10.0	39.4	88	.45	118
		Lot III—Alfalfa hay			
1944	10.7	40.4	72	.56	98
1945	10.1	65.3	162	.42	116
1946	9.3	34.6	82	.44	132
1947	9.9	28.9	62	.47	149
1948	9.5	36.0	78	.48	146
1949	9.9	34.8	94	.38	122
1950	10.0	34.9	79	.46	135
1951	10.2	37.5	84	.46	126
Average	9.9	39.6	90	.44	126

Table 9. - Summary of causes of lamb death losses as reported by lot and year

Years	1943			1944			1945			1946			1947		
Lots	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Stillbirths	3	2	1	0	0	1	1	3	1	4	5	2	5	3	2
Scours	8	5	1												
Not claimed	3		1	1					1	1*					
Cause unknown	5	1	3	1	1	3	1	2	2	2	6	5	4	1	2
Lack of milk	9	8													
Weak at birth		1											1		
Chilled		2													
Injury		1					1								
After docking									1			1			
Unaccounted for	4	0	0	0	3	0	9	10	12	0	3	3	0	2	0

Years	1948			1949			1950			1951		
Lots	I	II	III	I	II	III	I	II	III	I	II	III
Stillbirths	0	0	0	1	3	4	0	0	0	3	8	3
Scours												
Not claimed	1			8**	2	3	5	2				1
Cause unknown	16	6	5	18	2		1	8	3	18	14	5
Lack of milk									1	9	8	1
Weak at birth				2						4		
Chilled				2	3	1				2		
Injury					1					1		
After docking										1		
Unaccounted for	0	1	1	2	1	1	0	0	4	1	5	6

* Ewe dry
**4 not claimed and died

Table 10. - Lambs born dead within lots and years

Lot	I	II	III
1943	3*	2	1
1944	0	0	1
1945	1	3	1
1946	4	5	2
1947	5	3	2
1948	0	0	0
1949	1	3	4
1950	0	0	0
1951	3	8	3
Total	17	24	14

* 1942-43 one ewe in Lot I aborted January 20, 1943. Not included in Lot I lambing.

was highest for the group fed the low phosphorus ration. The average mortality was 21 percent for the ewes fed the low phosphorus ration compared with 12 percent and 4 percent for the ewes fed the low phosphorus plus bone meal ration and the alfalfa ration, respectively.

Lamb deaths during the first 48 hours were not consistently higher for the low phosphorus group for every year (Table 12). The low phosphorus fed ewes had a significantly higher mortality than ewes fed the other two rations during the first 48 hours for the years 1943, 1948, 1949 and 1950. For the years of 1943 and 1951, the mortality during the first 48 hours was high for the groups of ewes fed the low phosphorus ration and the low phosphorus ration plus bone meal. The percentage differences between the lamb deaths of the first 48 hours and the entire lactation period of all three rations were of the same order since the greater portion of the deaths took place soon after birth. It is noted that the relative differences in mortality of lambs of the three groups of ewes were not consistent from year to year.

The causes of lamb deaths are summarized and reported in Tables 9 and 10. Since it is difficult to determine the exact cause of the death of young lambs, a greater portion of the lamb deaths are reported under the heading of "cause unknown". The Montana Agricultural Experiment Station reported the autopsy findings of lambs posted as shown in Table 12. A comparison of the data of the two Tables, 9 and 13, indicates that there are many factors that may cause death losses of lambs of ewes fed normal rations. Lamb mortality of 9 to 16 percent is not uncommon under average lambing conditions.

It appears that a low milk supply is responsible for the greater portion of the loss of lambs from ewes fed the low phosphorus ration, especially the losses during the first 48 hours (Tables 6, 9, and 12). Previous studies of phosphorus deficiencies indicate that a low phosphorus intake interferes with normal milk production.

Table 11. - Percentage of death losses of lambs of the purebred band at the Montana Experiment Station, Bozeman, 1951-1952 (39).

Total lambs born	1244
Number born dead	67
Percent born dead	5.4
Total loss from birth to off forest	133
Percent loss from birth to off forest	12
Number of live lambs recorded	1177
Percent live lambs recorded at lambing	129
Total percent lamb losses	16

Table 12. - Summary of the percentage difference in lamb mortality during the first 48 hours, the total lamb mortality, and the significance of these differences

	First 48 Hours				Total			
Lots	I	II	III	Significance	I	II	III	Significance
1943	31	20	8	I/III** II/III**	47	31	8	I/III** II/III**
1944	4	2	5	None	4	6	5	None
1945	1	5	2	None	16	20	21	None
1946	8	7	3	None	10	20	14	None
1947	21	10	5	I/III**	21	12	7	I/III**
1948	25	8	7	I/ II** I/III**	28	15	11	I/ II* I/III**
1949	34	11	7	I/ II** I/III**	52	15	9	I/ II** I/III**
1950	8	0	1	I/III* I/ II**	8	10	8	None
1951	41	34	3	I/III** II/III**	41	34	16	I/III** II/III**

* Significantly different at the 5 percent level of probability
**Significantly different at the 1 percent level of probability

Table 13. - Death loss (autopsy findings) at the Montana Experiment Station, Bozeman[1] (39)

Pneumonia	28
Atelectasis (Stillborn)	
Complete	11
Partial	6
Dysentery	14
Starvation	13
No visible lesions	12
Liver rupture	9
Delayed parturition	8
Prepartum death	8
Enterotoxemia	4
All others	19
Totals[2]	132

[1] Dr. J. W. Stafford of the Veterinary Research Laboratory performed the autopsies
[2] This table concerns only the lambs posted.

The results of this study are in agreement with the findings reported in the literature, that a low phosphorus intake or a low phosphorus reserve in the body of the ewe will not affect the size and number of offspring. The data presented in Table 13 show the average birth weights of the lambs of the ewes fed the three rations to be approximately the same; 9.8, 10.0, and 9.9 pounds for Lots I, II, and III, respectively. The percent of lambs born of each group was not significantly different (Table 7).

The average daily gains of the lambs from birth to the time of weaning were not different. This may have been partially due to the fact that feed was available to all groups of lambs in a creep.

Table 14. - Ewe weight gains, losses, and wool weights by lot and by year

Year	Ewes in lot	Average ewe weight gain or loss	Average wool weight	Dry ewes	Ewes lost
	No.	lb.	lb.	No.	No.
		Lot I—Low phosphorus			
1943	60	—	—	26	3
1944	52	32.27	9.18	1	3
1945	57	-21.33	9.54	3	2
1946	36	-16.16	8.19	4	1
1947	38	-19.68	9.42	3	0
1948	39	-20.11	9.75	0	-
1949	30	- 6.36	9.28	2	6
1950	64	-21.60	9.22	5	5
1951	56	-13.28	9.83	-	-
		Lot II—Low phosphorus plus bone meal			
1943	60	—	—	19	1
1944	56	32.14	9.69	2	2
1945	59	- 9.83	9.84	2	2
1946	52	-15.16	8.79	1	1
1947	49	- 6.93	9.75	2	1
1948	40	-10.96	10.92	3	-
1949	54	3.44	9.13	4	3
1950	70	- 3.77	10.46	3	4
1951	66	- 8.16	10.96	-	-
		Lot III—Alfalfa hay			
1943	60	—	—	6	0
1944	54	29.17	9.46	2	2
1945	65	-10.65	10.68	2	0
1946	59	- 6.39	8.72	1	3
1947	49	- 3.34	9.84	1	0
1948	48	-12.54	9.94	3	-
1949	59	2.34	8.84	0	1
1950	71	- 8.58	10.82	6	4
1951	79	-16.98	9.78	-	-

Table 15. - Average difference in ewe weight losses among the lots and the level of significance of the differences

	Lot I minus Lot II	Lot I minus Lot III	Lot II minus Lot III
	Lb.	Lb.	Lb.
1944	0.13	3.11	2.98
1945	12.51**	10.68**	0.82
1946	1.00	9.77**	8.77**
1947	13.75**	16.34**	3.59
1948	9.15*	7.57	1.58
1949	9.80**	8.70**	1.10
1950	18.22**	13.02**	5.20
1951	5.13	3.69	8.82**

* Significantly different at the 5 percent level of probability
**Significantly different at the 1 percent level of probability

Since the ewes fed the low phosphorus ration had the highest percentage of lamb mortality (Table 6), the percent of lambs weaned of ewes lambed was the lowest for this group (Table 8). This was probably due to the low milk supply.

Dry Ewes, Ewe Losses, Abortions, Wool Production, and Weight Losses

Data relating to the effect of the level of phosphorus intake on the ewes used in this experiment are presented in Tables 14 and 15.

There were 26, 19, and 6 dry ewes in Lots I, II, and III, respectively during the season of 1942-1943. The reason for a large number of dry ewes during this season is probably due to the fact that yearling ewes were used. The ewes were all together while breeding and were on pasture and alfalfa hay. They were not divided into lots until the end of the breeding period. This was the beginning of the experiment and since the rations were not fed until after the end of the breeding season, the rations could not have affected the breeding of the ewes. After this initial division of ewes into lots, the same ewes were wintered in their respective lots each gestation period for the remainder of the experiment. During the remainder of the experiment the number of dry ewes occurring was rather evenly divided in the lots and there was no significant difference between the lots.

The losses as listed include those ewes lost from the end of the breeding season to the end of lambing. The overall losses were larger in Lot I than in Lot II or Lot III, being 20, 14, and 10, respectively. There were consistently greater losses in Lot I than there were in lots II and III. The cause of the loss was not recorded so it would not be accurate to attribute the difference to the phosphorus intake alone. However, several investigators, Black and Jones (7), Knox and Watkins (21), and DuToit et al. (9), have found that supplementing pastures low in phosphorus content with bone meal lowers the mortality as well as increasing wool, meat, and milk production.

The only abortion recorded occurred in Lot I, January 20, 1943. Since no others were recorded, it will be assumed that they were no higher in one lot than any other and probably no greater than would occur in any flock of sheep.

The average weight of the wool produced by the ewes of each lot is given in Table 15. There was no significant difference between the weight of the wool produced in any lot. Duerden and associates (8), found that when ewes were fed a phosphorus deficient ration there was a 32 percent reduction in fleece weight, a reduction in staple length of 16.6 percent, and 13.5 percent less fiber thickness. However, the ewes in their study received a much lower phosphorus intake—0.66 grams to 1.02 grams per one hundred pounds of liveweight. The ewes in the experiments of Duerden and associates remained on this ration for 2

years, or the duration of the study. The ewes in the present experiment were on good pasture during the summer and fall and so had a chance to build up phosphorus reserves. The ewes in this study also received larger amounts of phosphorus in their rations than did those of Duerden's study. These factors undoubtedly accounted for the fact that there was no difference between the fleece weights of the ewes fed different levels of phosphorus in this study.

The ewe weight losses during the period from the time of breeding until they were placed on pasture are reported in Table 15. An analysis of the significance of these differences is shown in Table 15, and was calculated by a method of least squares as outlined by Snedecor (34). The relative differences in losses of ewe weights among the three lots varied considerably. The ewes fed the low phosphorus rations had significantly greater losses in 5 of the 8 years. In 1 year the ewes of Lot II had significantly greater losses than Lot III, while in 1 year Lot III had a significantly greater loss than Lot II.

Blood Phosphorus Values

The data relating to factors affecting the blood phosphorus levels of pregnant and lactating ewes are shown in Table 16, Figures 1, 2, 3 and 4. The values obtained from the determinations of blood phosphorus of ewes from date of conception to approximately 100 days after lambing were used to study the effect of the stage of pregnancy and lactation, the size of lamb and the level of phosphorus intake on the phosphorus content of the blood. Third degree polynomial curvilinear regression curves were made and used in studying the changes in blood phosphorus levels of ewes during this period.

The approximate date of the pregnancy at which the blood sample was drawn was estimated by assuming a 150 day gestation period and subtracting from 150 days the number of days between the time of taking the blood sample and the exact birth date.

The lambs born to these ewes were divided into four weight groups as shown in Table 16.

Table 16. - Weight groups of lambs at birth and mean inorganic blood phosphorus levels of pregnant and lactating ewes used in Figures 1, 2, 3, and 4.

Birth weight (BW) Group No.	Type of birth	Weight of lambs lb.	Mean blood phosphorus values mg. Lot No. I	II	III
1	Singles	9.9 and below	3.71	4.60	4.85
2	Singles	10.0-11.9	3.31	4.54	4.67
3	Singles	12.0-15.6)	3.23	4.30	4.77
	Twins	11.4-16.9)			
4	Twins	17.0-23.2)	3.28	4.02	4.63
	Triplets	18.1-27.4)			

The curves of Figure 1 show the curvilinear regressions of the inorganic blood phosphorus on days of pregnancy and lactation for the low phosphorus fed ewes for birth weights of offspring of the following weight categories (Table 16), 9.9 pounds and below, 10.0 to 11.9 pounds, 12.0 to 16.9 pounds and 17 to 27.4 pounds. The blood of ewes producing lambs weighing 9.9 pounds or less maintain a normal inorganic blood phosphorus level value as the pregnancy advanced. The lowest value appeared about 10 days after the birth of the lamb, followed by a rapid recovery during the next 90 days. The blood phosphorus values increased to about 5 mg. per 100 cc. of blood within 90 days after lambing.

The inorganic blood phosphorus values of the second weight group of ewes, with lambs weighing from 10.0 to 11.9 pounds, were more or less linear with respect to the stages of pregnancy and lactation. This was considered to be due to the distribution of the samples obtained. The blood phosphorus values of the ewes giving birth to lambs weighing from 12.0 to 16.9 pounds exhibited a curve similar in shape to the curve for ewes of Group 1. The lowest values of mg. of phosphorus per 100 cc. of blood were about the time of the birth of the lamb, followed by a gradual rise during the next 90 days.

The curve of the ewes of Group 4 producing the heaviest lambs was similar in shape to the others with the exception that the

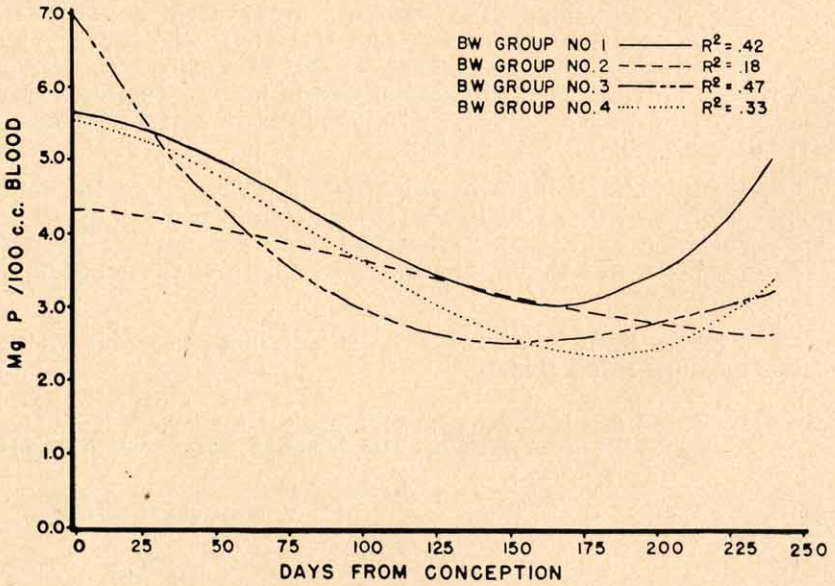

Figure 1. - Curvilinear regression curves of the inorganic phosphorus content of blood for groups of ewes producing four different weight-range groups of lambs on days of gestation plus lactation. These ewes were fed the low-phosphorus ration. R^2 = multiple correlation coefficient.

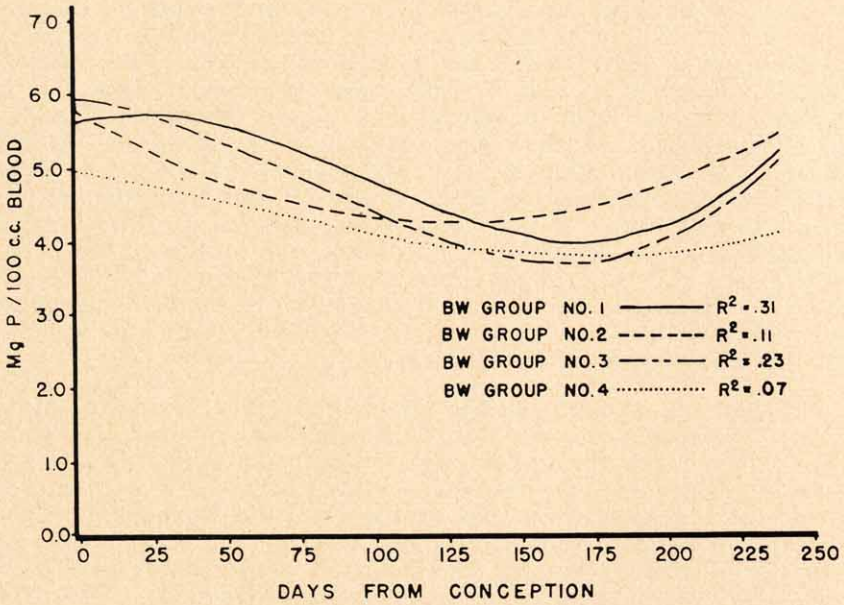

Figure 2. - Curvilinear regression curves of the inorganic phosphorus content of blood for groups of ewes producing four different weight-range groups of lambs on days of gestation plus lactation. These ewes were fed the low phosphorus ration plus bone meal. R^2 = multiple correlation coefficient.

blood phosphorus values dropped to about 2.33 milligrams per 100 cubic centimeters at about 30 days after the lambing date. A similar trend was observed in the curves for the four lamb-weight groups of ewes fed the high phosphorus ration of Lot II and the alfalfa fed ewes of Lot III (Figures 2 and 3). The exception was that the blood phosphorus values of the alfalfa-fed group of ewes was not so low at the time of the birth of the lamb as was the low-phosphorus-plus-bonemeal group of ewes. An exception in the trend of the regression of the blood phosphorus values on days of pregnancy and lactation was observed among the blood phosphorus values of the ewe classified in Group I of those receiving alfalfa hay (Figure 3, Lot III). This is considered to be due to insufficient numbers of samples and to the clustering of the samples taken about the time of the birth of the lamb and the early part of the lactation. It would be logical to assume that the blood phosphorus values of this group remained relatively constant throughout pregnancy and lactation since the blood phosphorus values of the heaviest lamb-producing group did not fall felow 3.9 milligrams per 100 cubic centimeters of blood (Figure 3).

Composite inorganic blood phosphorus values of all ewes fed each particular ration were used to make curvilinear regressions

of blood phosphorus on days of pregnancy and lactation (Figure 4). A distinct drop of the inorganic phosphorus values took place in the blood of ewes fed the low phosphorus ration. These values ranged from 0.98 in 1949 to 2.52 grams per ewe in 1944. It is evident that the level of phosphorus intake is reflected in the blood phosphorus values. The addition of bonemeal to the low phosphorus ration maintained a higher level of inorganic blood phosphorus throughout the entire gestation and lactating periods than was maintained in the blood of the ewes fed the same ration without bone meal (Lot I). The phosphorus intake of the bonemeal group (Lot II) ranged from 2.90 to 5.51 grams per ewe per day. The trend of the regression curve was of the same order as the inorganic blood phosphorus curve of the group of ewes fed the low phosphorus ration (Lot I).

The group of ewes fed the alfalfa hay (Lot III) as the main source of phosphorus, maintained the highest level of inorganic blood phosphorus throughout the entire gestation and lactation periods. The level of phosphorus intake of these ewes was not consistently greater than that of the bone meal group (Lot II). This would indicate that alfalfa hay used as the main source of roughage during pregnancy and lactation would supply sufficient phosphorus for the average pregnant and lactating ewe. This fact

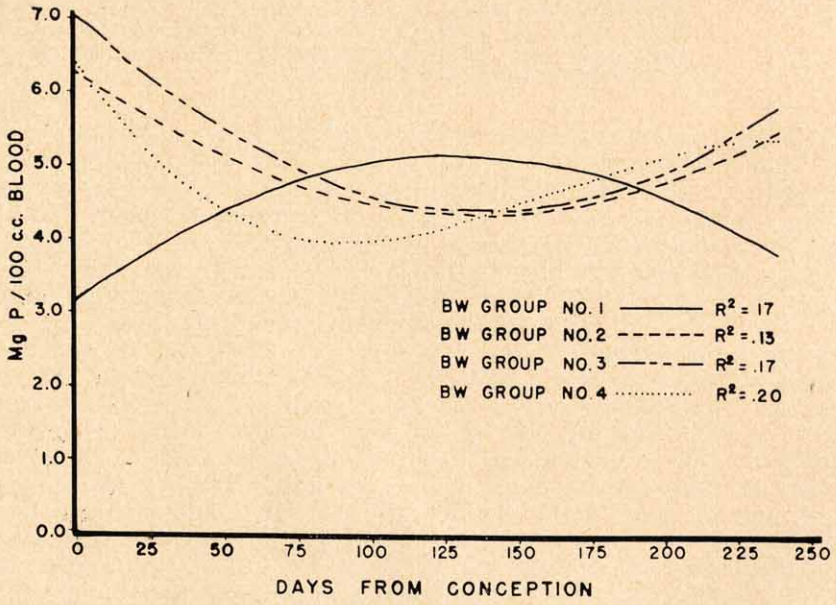

Figure 3. - Curvilinear regression curves of the inorganic phosphorus content of blood for groups of ewes producing four different weight - range groups of lambs on days of gestation plus lactation. These ewes were fed the alfalfa hay ration. R^2 = multiple correlation coefficient.

is supported by the work of Lofgreen and Kleiber (22), (23), who found that 94 percent or more of the phosphorus of alfalfa hay was available and utilized by the steer.

It is noted that the trend of the blood phosphorus curve of Lot III is similar to that of the other two lots of ewes. In other words, a reduction in the inorganic blood phosphorus during pregnancy is a characteristic phenomenon. The rate of reduction will depend on the size and number of lambs as well as the level of phosphorus intake of the ewe during the gestation period.

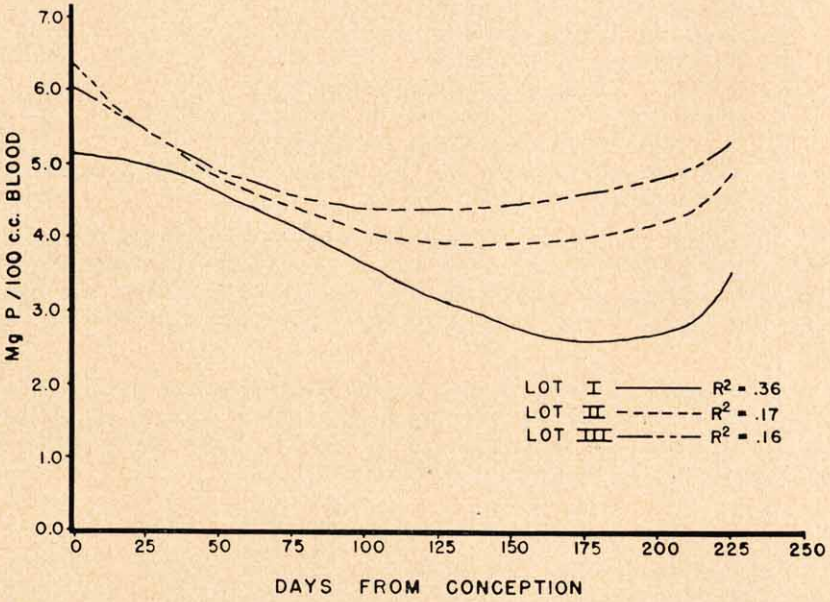

Figure 4. - Curvilinear regression curves of the inorganic phosphorus content of blood for groups of ewes fed the three different rations on days of gestation and lactation. R^2 = multiple correlation coefficient.

CONCLUSIONS

The low phosphorus ration caused:

1. Higher lamb mortality during the first 48 hours of the lamb's life.
   This could have been due to the low milk yield of the ewes.
2. Greater loss in ewe weight during gestation and lactation.

A low phosphorus intake of pregnant and lactating ewes had no effect upon:

1. Percentage of lambs born to ewes bred
2. Percentage of ewes lambing
3. Percentage of live lambs born
4. Average birthweight of the lambs
5. Percentage of stillbirths
6. Number of abortions occurring
7. Percentage of lambs born as multiple births
8. Average wool production of the ewes
9. Average daily gain of the lambs, probably because all the lambs were creep fed.

The blood phosphorus level of the ewes receiving alfalfa hay maintained higher values than those receiving bone meal, even though the intake of phosphorus of the ewes receiving the bone meal was equal to or greater than those receiving the alfalfa hay.

A minimum intake of 0.11 percent phosphorus in the ewe's ration was sufficient for the production of a normal lamb, but insufficient for the initiation of sufficient milk production to feed the lamb at the time of parturition.

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References

1. Beeson, W. M., C. W. Hickman, and R. F. Johnson, 1945. "Calcium and Phosphorus for Breeding Ewes." Flour and Feed, 46:12-13.

2. Beeson, W. M., C. W. Hickman, D. W. Bolin and E. F. Rinehart, 1939. Fall and Winter Range Plants Found to be Low in Phosphorus. 47th Annual Report, Ida. Agr. Expt. Sta. Bul. 236, p. 8-9.

3. Beeson, W. M., D. W. Bolin and C. W. Hickman, 1937. "The Phosphorus Requirements of Sheep." Proc. Am. Soc. of Animal Prod. 345-350.

4. Beeson, W. M., R. F. Johnson, D. W. Bolin, and C. W. Hickman, 1945. The Phosphorus Requirement of Ewes for Pregnancy and Lactation. Ida. Agr. Expt. Sta. Bul. 266, p. 1-11.

5. Beeson, W. M., R. F. Johnson, D. W. Bolin and C. W. Hickman, 1944. Unpublished data, Ida. Agr. Expt. Sta.

6. Becker, R. B., W. M. Neal and A. L. Shealy, 1933. Stiffs or Sweeny (Phosphorus Deficiency) in Cattle, Fla. Agr. Expt. Sta. Bul. 26, p. 27.

7. Black, W. H. and L. H. Jones, 1949. Comparison of Methods of Supplying Phosphorus to Range Cattle. U.S.D.A. Tech. Bul. 981.

8. Duerden, J. E., V. Bosman, and P. S. Botha, 1932. "Influence of Phosphorus and other Minerals on Wool Growth." Eighteenth Report of the Dir. of Veterinary Service and Animal Industry, Union of South Africa, 631-649.

9. DuToit, P. J., A. I. Malan, and J. W. Groenewald, 1932. Phosphorus in the Nutrition of Sheep (Final Report). Studies in Mineral Metabolism XVIII, Eighteenth Report of the Director of Veterinary Services and Animal Industry, Union of South Africa, 611-630.

10. DuToit, P. J., A. I. Malan, and S. D. Roussouw, 1930. Phosphorus in the Sheep Industry, Preliminary Report, 1930. Sixteenth Report of the Director of Veterinary Services and Animal Industry, Union of South Africa, 313-326.

11. DuToit, P. J., A. I. Malan, and J. W. Groenewald, 1931. Phosphorus in the Nutrition of Sheep. Studies in Mineral Metabolism XVII, Seventeenth Report of the Director of Veterinary Services and Animal Industry, Union of South Africa, 453-472.

12. Eckles, C. H., and T. W. Gullickson, 1927. "The Relation of Phosphorus Deficiency to the Utilization of Feed." Am. Soc. Animal Prod. Proc. 16:16-21.

13. Fraps, G. S., 1918. Mineral Requirements of Sheep. Tex. Agr. Expt. Sta. Bul. 232.

14. Gallup, W. D. and H. M. Briggs, 1950. "The Minimum Phosphorus Requirement of Lambs for Phosphorus Equilibrium." J. Animal Sci. 9:426-430.

15. Greaves, J. E., E. J. Maynard, and Wendel Reeder, 1934. Influence of Calcium Phosphorus Intake on Bovine Blood. J. Agr. Res. 48, 0.1033-1041.

16. Hart, E. B., H. Steenbock, O. L. Kline, and G. C. Humphrey, 1931. "Dietary Factors Influencing Calcium Assimilation." J. Dairy Sci. 14:307.

17. Hart, G. H., H. R. Guilbert, and H. Goss, 1932. Seasonal Changes in the Chemical Composition of Range Forage and Their Relation to Nutrition of Animals. Calif. Agr. Expt. Sta. Bul. 543, 1-62, Berkeley, Calif.

18. Holm, G. C. and D. W. Bolin, 1944. Abortions in Range Ewes Investigated. Ida. Agr. Expt. Sta. Bul. 255, 8-10.

19. Johnson, S. R., 1939. The level of Inorganic Phosphorus in the Blood of Dairy Cattle. J. Nutr., 17, p. 15-21.

20. Kleiber, Max, Harold Goss, and Harold R. Guilbert, 1936. "Phosphorus Deficiency Metabolism and Food Utilization in Beef Heifers." J. of Nutr. 12:121-153.

21. Knox, J. H., and W. E. Watkins, 1942. The use of Phosphorus and Calcium Supplements for Range Livestock in New Mexico. N. Mex. Agr. Expt. Sta. Bul. 287, 1-18.

22. Lofgreen, G. P., and Max Kleiber, 1953. "The Availability of the Phosphorus in Alfalfa Hay." J. Animal Sci. 12 No. 2, 366-371.

23. Lofgreen, G. P. and Max Kleiber, 1954. Further Studies on the Availability of Phosphorus in Alfalfa Hay. J. Animal Sci. 13:258-264.

24. Madsen, L. L., 1939. "Effects of Dietary Deficiencies on Feed Utilization and Health of Farm Animals." Food and Life. U. S. Yearbook of Agr. 438-443.

25. Miller, R. F., G. H. Hart, and H. H. Cole, 1942. Fertility in Sheep As Affected by Nutrition During the Breeding Season and Pregnancy. Univ. Calif. Col. Agr. Expt. Sta. Bul. 672, 1-31.

26. Mitchell, H. H., 1947. "Mineral Requirements of Farm Animals." J. Animal Sci. 6:365.

27. Mitchell, H. H., and F. J. McClure, 1937. Mineral Nutrition of Farm Animals. Nat. Res. Council Bul. 99.

28. Morrison, F. B., Feeds and Feeding, 1951. Twenty-first Ed., The Morrison Pub. Co., Ithaca, New York, 1-1207.

29. Morris, S., and S. C. Ray, 1939. "The effect of a Phosphorus Deficiency on the Protein and Mineral Metabolism of Sheep." Biochem. J. 33:513.

30. Otto, J. S., 1932. Studies in Mineral Metabolism XXII. Phosphorus Calcium and Protein. Eighteenth Report of the Dir. of Veterinary Services and Animal Industry, Union of South Africa, 701-703.

31. Palmer, L. S., T. W. Gullickson, W. L. Boyd, C. P. Fitch, and J. W. Nelson, 1941. "The Effect of Rations Deficient in Phosphorus and Protein on Ovulation, Estrous, and Reproduction of Dairy Heifers" J. Dairy Sci. 24:199-210.

32. Pearson, P. B., H. M. Briggs, W. G. Kammlade, J. I. Miller, and R. F. Miller, 1949. Recommended Nutrient Allowances for Sheep. Nat. Res. Council, 1-24.

33. Saarinen, P., 1950. A Statistical Study of the Effect of Excessive Feeding of Calcium and Phosphorus Supplements on the Blood Calcium and Phosphorus of Dairy Cattle. J. of the Sci. Agric. Soc. of Finland, 22, p. 122-131.

34. Snedecor, G. W., 1950. Statistical Methods. 4th ed., Iowa State Col. Press, Ames, Iowa.

35. Stucky, H. R., 1945. Montana Sheep Ranch Study. Preliminary Rpt., Mont. Agr. Expt. Sta., Bozeman, Mont.

36. Theiler, A., H. H. Green, and P. J. DuToit, 1927. Minimum Mineral Requirements in Cattle. J. Agr. Sci. 17:291-314.

37. Theiler, Arnold, and H. H. Green, 1932. "Aphosphorosis in Ruminants," Nutr. Abst. and Rev., 1:359-385.

38. Van Horn, J. L., Gene F. Payne, James Drummond, and F. S. Willson, 1951. Nutritional Requirements of Ewes Wintered Under Range Conditions. Mont. St. Col. Agr. Expt. Sta. Progress Prt. for 1950-51, Mimeo. Circ. 63, 1-18, Bozeman, Mont.

39. Van Horn, J. L., O. O. Thomas, A. E. Flower, James Drummond, and Art Hoversland, 1953. Value of Dehydrated Alfalfa for Growth, Wool Production, and Reproduction in Sheep. Mont. St. Agr. Expt. Sta. Progress Rpt. for 1951-52, Mimeo. Circ. 70, 1-16, Bozeman, Mont.

40. Van Horn, J. L., Wm. H. Burkitt, A. E. Flower, James Drummond, and Art Hoversland 1952. Value of Dehydrated Alfalfa for Growth, Wool Production, and Reproduction in Sheep. Mont. St. Col. Agr. Expt. Sta. Progress Rpt. for 1950-51, Mimeo. Circ. 62, 1-15, Bozeman, Mont.

41. Van Horn, J. L., Wm. H. Burkitt, G. F. Payne, G. C. Hughes, and F. S. Willson, 1950. Nutritional Requirements of Ewes Wintered Under Range Conditions. Mont. Agr. Expt. Sta. Progress Rpt. 1948-49, 1-11, Bozeman, Mont.

42. Van Horn, J. L., Wm. H. Burkitt, Gene F. Payne, G. C. Hughes, and F. S. Willson, 1951. Nutritional Requirements of Ewes Wintered Under Range Conditions. Mont. St. Col. Agr. Expt. Sta. Second Annual Progress Rpt. 1949-50, 1-16, Bozeman, Mont.