NUTRITION OF GRAZING CATTLE

2. Estimation of Phosphorus and Calcium in Pasture Selected by Grazing Cattle

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SUMMARY

Linear regressions of phosphorus in pasture samples representative of pasture selectively grazed by cattle on phosphorus in organic-matter faeces are developed for six pasture types.

A linear regression is calculated for the six pasture types.

Estimates of phosphorus percentage from this regression in feeds fed to stalled cattle are compared with analytical values of phosphorus percentage in these feeds. Agreement is satisfactory.

Regressions of calcium in selectively grazed pasture on calcium in organic-matter faeces are developed.

The effect of calcium in drinking water is an appreciable source of error in the regression of calcium in pasture on calcium in organic-matter faeces.

The accuracy of estimates from regression of phosphorus and calcium in selectively grazed pasture is not increased by including other variables in multiple regression analysis.

I. INTRODUCTION

A technique for sampling pasture which is representative of pasture selected by grazing cattle has been described (Moir 1960). A regression of protein percentage in pastures sampled by this technique on protein percentage in organic-matter faeces was developed. Data derived from this regression agreed satisfactorily with similar data calculated from published digestibility trials on pasture grasses. This observation supported the validity of the pasture sampling technique in yielding samples representative of pasture selectively grazed.

In the present investigation of a relationship between pasture and faecal phosphorus and pasture and faecal calcium, the samples of faeces and of pasture from the previous investigation are used. A general relationship could be expected, as phosphorus and calcium excreted by cattle are mainly in the faeces. If estimates of phosphorus and calcium in selectively grazed pasture are to be made using this relationship, it could be expected that adjustments would be necessary for the amounts of these elements required for milk production, gestation and growth.

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During the course of the previous investigation, average milk yields of herds, and in some cases the milk yields of individual cows, were recorded. Milk production is therefore a measured variable in this investigation of the relationship between pasture and faecal phosphorus and calcium. The effect of gestation is largely controlled when milk production is measured. The demands for phosphorus and calcium for foetal development are appreciable only in late gestation. Cows in late gestation are dry cows or low-producing cows in late lactation. Growth is also largely controlled in this investigation, as faecal samples were taken mainly from milking herds and samples from very young animals were therefore excluded.

Another variable considered is dry-matter digestibility, which may exert an effect on phosphorus and calcium content of faeces. As the dry-matter digestibility of pasture grass roughly parallels the protein content of the grass and as a relationship exists between protein in pasture and protein in organic-matter faeces, either pasture protein or faecal protein may be used as a comparative index of dry-matter digestibility. The broad application of the equation derived by Lancaster (1954) for estimating organic-matter digestibility from faecal protein was referred to previously (Moir 1960). This equation may be used for estimating dry-matter digestibility on a more absolute basis.

The procedure of Moir (1960) was used for sampling pasture and faeces.

For the estimation of phosphorus and calcium, the ash from 2 g dry-matter samples of pastures or of faeces was evaporated to dryness with 15 ml concentrated HCl, a further 10 ml concentrated HCl was added, and after warming the volume was made up to 200 ml with distilled water and allowed to stand.

The colorimetric method of the Association of Official Agricultural Chemists (1950) was used to estimate phosphorus on aliquots of the acid-soluble ash.

Calcium was estimated on a semi-micro scale by potassium permanganate titration of precipitated calcium oxalate.

III. EXPERIMENTAL AND RESULTS

The minimum number of faecal sub-samples required to give samples representative of the faeces of the herd in respect to phosphorus and calcium was determined from data derived from samples collected in the previous investigation (Moir 1960). These samples were taken from two groups of 10 cows paired in respect of milk production in each of 20 herds. Percentages of phosphorus and calcium in these samples of faeces were calculated on an organic-matter basis and details of statistical analysis of these data are given in Table 1.

	Phosphorus	*Calcium*
Standard error of means of 10 samples =	0·034	0·071
Standard error of means of 20 samples =	0·024	0·050

TABLE 1

Statistical Analysis of Data from Faecal Samples from Paired Groups of 10 Cows in each of 20 Herds

Source	D.F.	Mean Squares	
		Phosphorus	Calcium
Between farms	19	0·04729	0·33677
Between duplicates	20	0·00117	0·00504

As pairing in respect of milk production is more effective than correcting for milk production, these results under-estimate the standard errors of samples taken from a cross-section of a milking herd. However, these standard errors indicate that at least 20 sub-samples from a herd are preferred.

(a) Relationship of Phosphorus in Selectively Grazed Pasture and in Organic-matter Faeces

Percentages of phosphorus in dry-matter pasture and in organic-matter faeces for the six pasture types previously sampled are plotted in Figure 1. The data appear to be adequately defined by linear regression. Details of the statistical analysis of these data are given in Table 2.

TABLE 2

Statistical Analysis of the Linear Relationship Between Phosphorus in Dry-matter Pasture and in Organic-matter Faeces

Predominant Grass in the Diet	No. of Samples	Mean of y	Mean of x	Regression Coefficient	Residual Mean Square
Carpet grass (A)	20	0·177	0·369	0·291	0·001189
Couch grass (C)	8	0·216	0·447	0·400	0·001490
Forest grass (F)	10	0·159	0·349	0·379	0·001523
Rhodes grass (R)	3	0·303	0·557	0·013	0·000598
Paspalum grass (P) ..	22	0·269	0·587	0·218	0·001371
Kikuyu grass (K)	11	0·315	0·699	0·312	0·002069
Within pasture types				0·295	0·001579

There is no evidence of heterogeneity among the six residual mean square (X^2 for 5 D.F. : 1·2 corresponding to a probability of 0·95) or among the slopes of the six regression lines:—

——	D.F.	M.S.
Average regression	1	0·1366
Among regressions	5	0·0022
Residual	62	0·0014

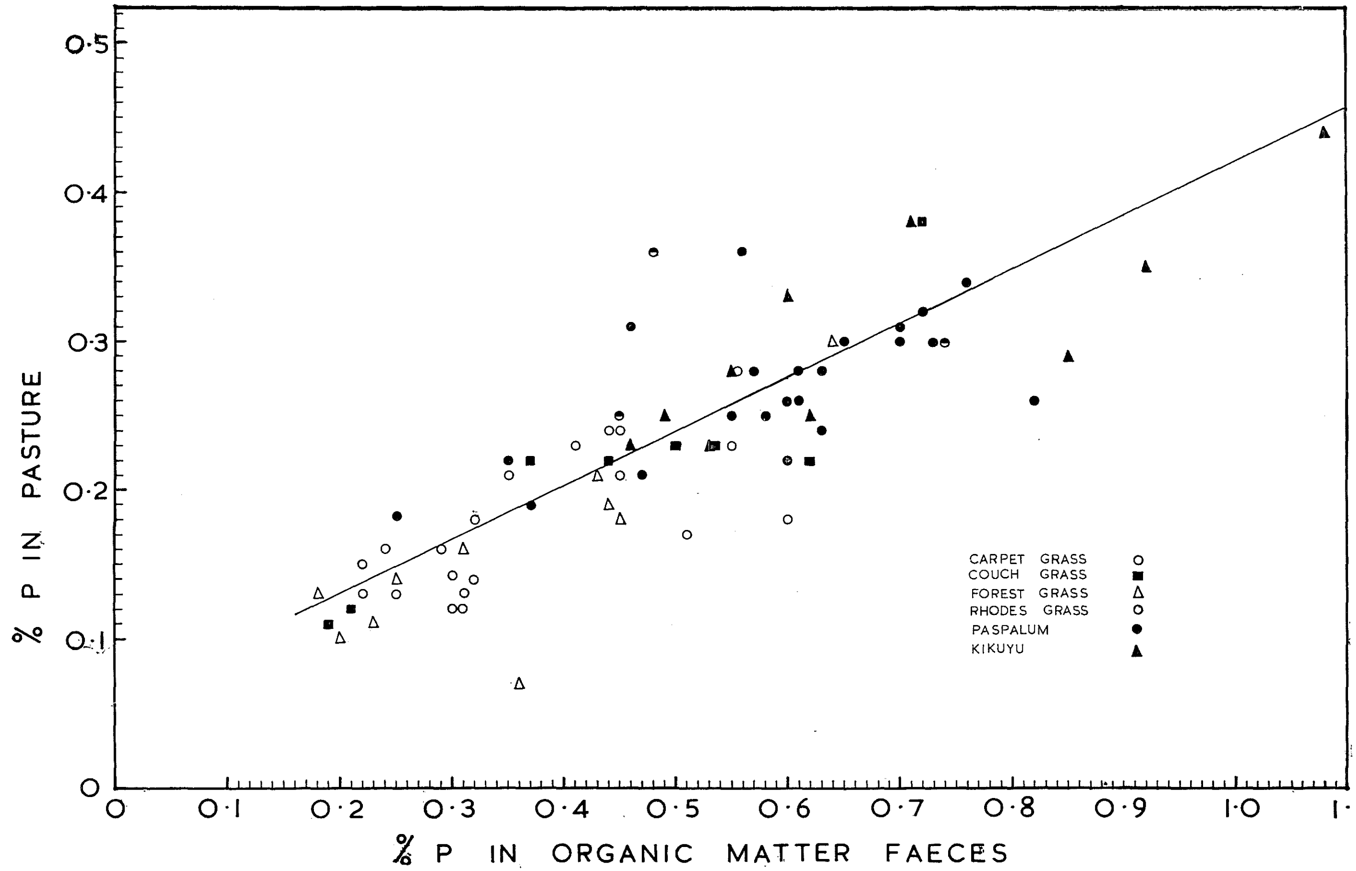

Fig. 1.—Relationship between phosphorus in dry-matter pasture and in organic-matter faeces.

However, there are significant differences among the pasture means:—

—	D.F.	Mean Square
Regression on x_1	1	0·13661***
Residual within pastures	67	0·00158
Pastures adjusted for regression	5	0·00420*

* = significant at the 5% level.
*** = significant at the 0·1% level.

Adjusted Means—

F	0·202
A	0·214
C	0·230
P	0·242
K	0·255
R	0·285

There are no significant differences within the brackets. Other differences are significant at 5 per cent. and 1 per cent. levels.

From the above analyses the estimating equation is—

$$y = p - 0{\cdot}146 + 0{\cdot}295\, x_1 \pm 0{\cdot}04,$$

where p is the appropriate adjusted mean.

If it is assumed that the pasture effects are a sample from a population of pasture effects or sampling errors, an overall relationship can be estimated by component analysis. Details of this analysis are given in Table 3.

TABLE 3

Components of Variance and Co-variance for Among, Within and Among Plus Within Pasture Types

Source	Components of Variance and Co-variance		
	(y^2)	(xy)	(x_1^2)
Among	0·003742	0·008421	0·018722
Within	0·003564	0·006813	0·023111
Among + Within	0·007306	0·015234	0·041833

From these data the regression estimate from among plus within line is calculated as—

$$y = 0{\cdot}057 + 0{\cdot}364\, x_1$$

(b) Relationship of Calcium in Selectively Grazed Pasture and in Organic-Matter Faeces

Percentages of calcium in dry-matter pasture and in organic-matter faeces for six pasture types are plotted in Figure 2. The data appear to be adequately defined by linear regression. Details of the statistical analyses of these date are given in Tables 4 and 5.

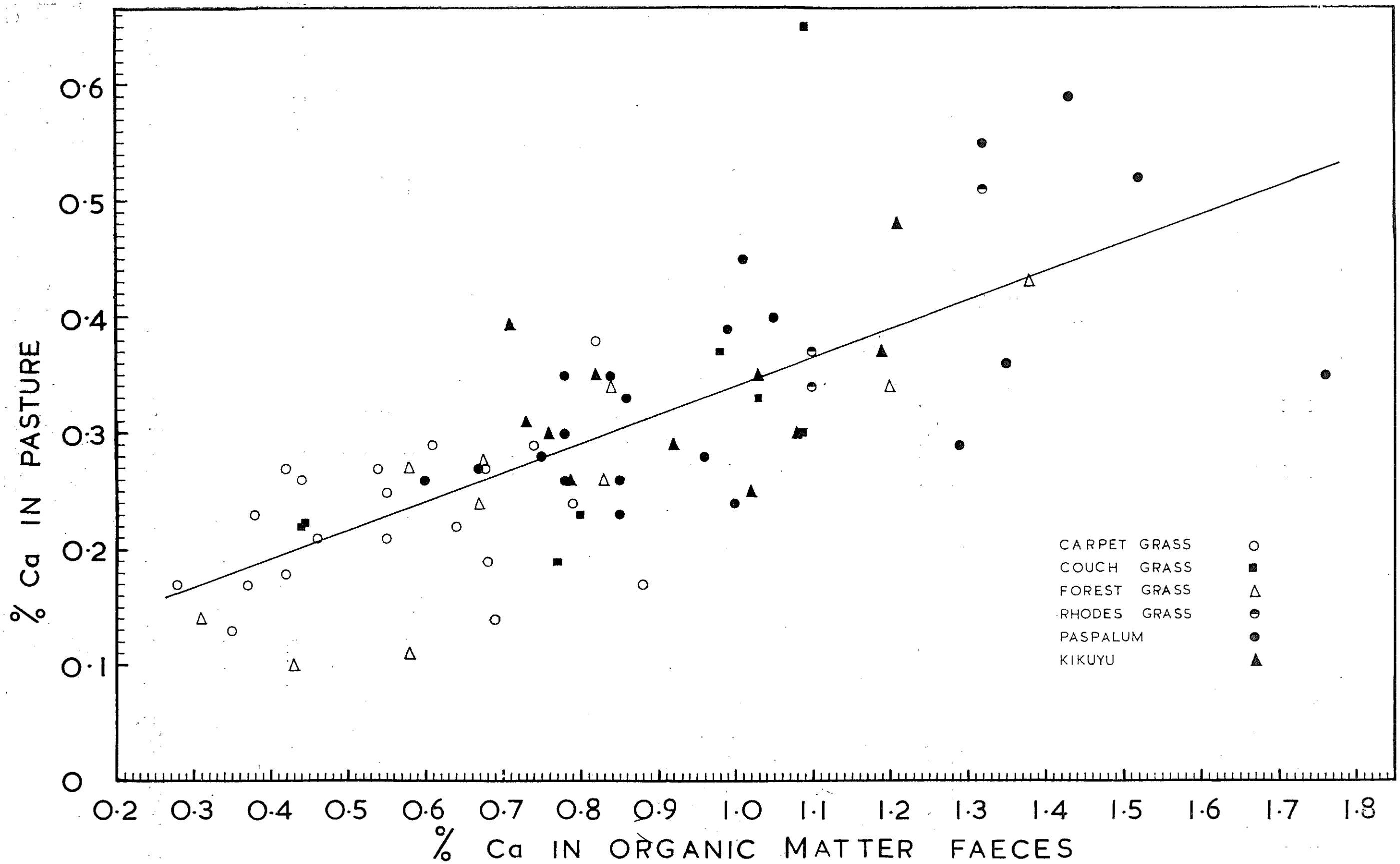

Fig. 2.—Relationship between calcium in dry-matter pasture and in organic-matter faeces.

TABLE 4

Analysis of Variance for Calcium in Pasture and in Organic-matter Faeces

Source	D.F.	Mean Square
Among pastures .. .. (adjusted for regression)	5	0·00217 N.S.
Regression	1	0·22458***
Residual	66	0·00550

N.S. = Not significant.
*** = Significant at the 0·1% level.

TABLE 5

Regression of Calcium in Pasture on Calcium in Organic-matter Faeces

Source	D.F.	Mean Square
Regression on x ..	1	0·43221***
Residual	71	0·00556

*** = Significant at the 0·1% level.

The among pasture differences in Table 4 are not significant. Ignoring pasture differences leads to the analysis in Table 5.

These results lead to the estimate—

$$y = 0\cdot092 + 0\cdot247x \pm 0\cdot074.$$

(c) Effect of Milk Production and Dry-matter Digestibility on Regressions for Phosphorus and Calcium

Several regression forms were fitted in turn, using the sums of squares and products of these variates within the six pasture types. These were:—

(i) $y = a + bx_1 + cx_5$

(ii) $y = a + bx_3$

(iii) $y = a + bx_1 + cx_3$

(iv) $y = a + bx_1 + cx_3 + dx_5$

(v) $y = a + bx_1 + cx_4$

The terminology used is—

$y =$ *per cent.* P or *per cent.* Ca in dry-matter pastures.

$x_1 =$ *per cent.* P or *per cent.* Ca in organic-matter faeces.

$x_2 =$ *per cent.* protein in organic-matter faeces.

x_3 = *per cent.* P or *per cent.* Ca in dry-matter faeces multiplied by the estimated dry-matter indigestibility: i.e. $x_3 = zx_1 (u + vx_2)$, where u and v are constants suggested by Lancaster for estimating feed-to-faeces ratio and hence dry-matter digestibility, and z is an adjustment for the ratio of organic matter to dry matter.

$x_4 = x_1 \cdot x_2$.

x_5 = milk production (herd average in lb).

The residual mean squares were not reduced when these forms were fitted to the calcium data.

Only the form $y = a + bx_1 + cx_3$ significantly reduced the residual mean squares for the phosphorus data. This suggests that the values of u and v used in calculating x_3 are not optimal for this set of data. In this regard Lancaster did find significant differences among what would be called in this analysis his "u" values. Details of the analysis of the form $y = a + bx_1 + cx_3$ are given in Tables 6 and 7.

TABLE 6

Statistical Analysis of the Form $y = a + bx_1 + cx_3$

Source	D.F.	Mean Square
Regression on x_3	1	0·14238***
Extra due to x_1	1	0·00800*
Residual within pastures	66	0·00139
Pastures adjusted for x_3 and x_1 ..	5	0·00305 N.S.

*** = significant at the 0·1% level.
* = significant at the 5% level.
N.S. = not significant.

TABLE 7

Statistical Analyses of the Form $y = a + bx_1 + cx_3$ when Differences Among Pastures are Ignored

Source	D.F.	Mean Square
Regression on x_3	1	0·33961***
Extra due to x_1	1	0·03067***
Residual	71	0·00151

*** = significant at the 0·1% level.

The estimating equation is—

$$y = 0{\cdot}0247 + 0{\cdot}2103x_1 + 0{\cdot}6831x_3 \pm 0{\cdot}039.$$

(d) Comparison of Phosphorus and Calcium Estimated from Regression with Values Derived from Analyses of Feeds

Details of the comparison of phosphorus and calcium estimated from regression with values derived from analyses of feeds fed to stalled animals are summarized in Table 8. The animals recorded were fed for three weeks on each feed. Samples of feeds and faeces were collected twice daily during the second half of each period and analyses were made on bulked samples.

TABLE 8

Comparison of Percentages of Phosphorus and Calcium Estimated from Regression with Values Derived from Analyses of Feeds Fed to Stalled Animals

Animal Identification	Milk (lb)	Feed	Faecal Composition (Organic-matter basis)		Feed Composition Observed (Dry-matter basis)		Feed Composition Estimated (Dry-matter basis)	
			P (%)	Ca (%)	P (%)	Ca (%)	P (%)	Ca (%)
A	0	Oaten hay	0·25	0·38	0·13	0·15	0·15	0·19
B	0		0·28	0·33			0·16	0·17
A	8	Oaten hay	0·28	0·39	0·13	0·16	0·16	0·19
B	6		0·26	0·35			0·15	0·18
A	0	Lucerne hay	0·74	2·46	0·35	1·05	0·33	0·70
B	0		0·76	2·53			0·33	0·72
A	11	Lucerne hay	0·71	2·25	0·36	0·97	0·32	0·65
B	10		0·68	2·24			0·30	0·65
C	21	Lucerne hay	0·83	3·76	0·38	1·54	0·36	1·02
D	13		0·86	3·73			0·37	1·01
C	25	Lucerne hay	0·74	3·61	0·33	1·45	0·33	0·98
D	18		0·72	3·44			0·32	0·94
E	0		0·87	3·86			0·37	1·05

The estimated percentages of phosphorus are within the standard error of estimate for the regression relating pasture and faecal phosphorus. There is unsatisfactory agreement between the estimated and observed percentages of calcium in the feed.

Regression analysis of the observed percentages of calcium in feeds on the percentages of calcium in organic-matter faeces from Table 8 yields the equation

$$y = 0{\cdot}0189 + 0{\cdot}4049\,x \pm 0{\cdot}03$$

IV. DISCUSSION

The linear regression of phosphorus percentage in selectively grazed pasture on phosphorus percentage in organic-matter faeces developed for each of the six pasture types may be used to estimate the order of magnitude of the phosphorus levels in these selectively grazed pastures.

The regression equation developed by component analysis when pasture differences are ignored gave estimates of phosphorus percentage in the diets of stall-fed animals (Table 8) which when compared with the analysed percentages of phosphorus in these diets were within the standard error of 0·04 per cent. phosphorus. The satisfactory application of this regression to an entirely different set of conditions and to different feed types suggests that this regression could be used generally to distinguish low, moderate and high phosphorus levels in the diets of cattle.

The linear regression of calcium in selectively grazed pasture on calcium in organic-matter faeces gave estimates of calcium in the diets of the stall-fed cattle which were considerably less than the analysed percentages of calcium in these diets. Also the slope of the regression of calcium in pasture on calcium in organic-matter faeces is considerably less than the slope of regression of phosphorus in pasture on phosphorus in organic-matter faeces. These observations suggested that calcium in the pasture samples analysed under-estimated the total calcium intake. The possibility that an appreciable amount of calcium was supplied by the drinking water was subsequently investigated. Analyses of water samples from 35 of the farms revealed that the calcium content of these water samples ranged from 0·03 to 1·73 g Ca per gal and the mean was 0·24 g. A high calcium content in water from relatively few farms could appreciably affect the slope of the regression line and could contribute to the high standard error of 0·073 calcium. The high standard error is also possibly due to errors in sampling pastures containing white clover, as the calcium content of white clover may be several times as great as the calcium content of grasses.

The linear regression of calcium in selectively grazed pasture on calcium in organic-matter faeces developed by component analysis for the six pasture types may be used to estimate the order of magnitude of the calcium levels in these selectively grazed pastures. The linear regression of calcium in feeds on calcium in organic-matter faeces developed from data recorded in Table 8 may be used to estimate the order of magnitude of the total ingested calcium.

As the inclusion of milk production and dry-matter digestibility as measured variables in the regression analyses did not improve the accuracy of estimates of phosphorus or calcium in selectively grazed pasture, it must be concluded that their effects on these regressions are small. Small effects of milk production may be explained by (1) the compensating effect of late gestation in low-producing cows; (2) the replacement of depleted body reserves by low-producing cows; and (3) lower feed intakes of low-producing cows.

Small effects due to milk production or dry-matter digestibility on the regression of pasture and faecal phosphorus would be unlikely to be detected because of a correlation between pasture phosphorus and milk production and between pasture phosphorus and dry-matter digestibility. These effects are therefore virtually accounted for in the one linear regression. No conclusions can be made in respect of calcium, as errors in the data used are high.

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