HYPOMAGNESAEMIA IN MILKING COWS: THE RESPONSE OF SERUM MAGNESIUM TO ALTERATIONS IN HERBAGE COMPOSITION RESULTING FROM POTASH AND NITROGEN DRESSINGS ON PASTURE [1])

A. KEMP

Institute for Biological and Chemical Research on Field Crops and Herbage, Wageningen, Netherlands

SUMMARY

1. A heavy potash dressing of pasture in the form of muriate of potash leads to a substantial increase in potassium and chlorine in the herbage, and at the same time sodium, magnesium, calcium and sulphate are reduced. Phosphate is unaffected (Figs. 3 and 8, table 10). The magnesium reduction averages 15 to 20 % of the untreated herbage (Fig. 6).
2. A heavy application of nitrogen in the form of nitro-chalk increases crude protein, sodium, calcium and magnesium (Figs. 2, 4, 6, 7 and 9, table 11). With higher potassium levels the potassium in the herbage increases as a result of a heavy nitro-chalk dressing. With low potassium levels the potassium in the herbage decreases. This inverse relationship of potassium to nitrogen was found to occur at potassium levels in herbage of less than 2 % in dry matter (Fig. 5).
3. Compared with summertime conditions, there is less magnesium in the herbage in early spring and late autumn and more crude protein (Figs. 8, 9, 1 and 2).
4. Heavy potash and nitrogen dressings, whether, separately or combined, cause the serum magnesium levels to fall. Six cows showed clinical symptoms of hypomagnesaemic tetany (tables 12 and 13).
5. A significant positive correlation was found between the serum magnesium levels and the magnesium contents of the herbage in the week preceding blood sampling (Figs. 10 and 11). In 822 cows, 23 of which were suffering from hypomagnesaemic tetany with serum magnesium levels lower than 1.0 mg Mg/100 ml, no low serum magnesium levels were found when the magnesium content of the herbage contained more than 0.20 % of Mg in dry matter. When the herbage magnesium fell below 0.20 % both very low and normal serum magnesium values were observed (Figs. 10 and 11).
6. Significant negative correlations were found between the serum magnesium concentrations and the crude protein contents of the herbage, and between the serum magnesium levels and the percentages of potassium in the herbage (partial correlations) (Fig. 12).
7. The variation in the serum magnesium levels with constant magnesium contents of the herbage is attributed to differences in magnesium intake by the cows or in the utilisation of the ingested magnesium, this possibly being influenced by the various fertilizer treatments and the composition of the herbage ingested.
8. No relationship could be found between the daily milk production and the serum magnesium levels.

INTRODUCTION

In 1956 and 1957 grazing experiments were carried out at the "Droevendaal" Experimental Farm, Wageningen, the object being to dertermine the effect of various applications to the pasture of nitrogen, phosphate and potash on the chemical composition of the herbage in connection with the serum magnesium levels in milking cows and the incidence of hypomagnesaemic tetany. Some of the results relating to the serum magnesium levels have already been published (KEMP 1958 and 1959).

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The present report discusses in turn the relationship between the fertilizer treatment of the pasture and the chemical composition of the herbage, and the relationship between the chemical composition of the herbage and the serum magnesium concentrations.

Data on the layout of the experimental fields, the fertilizer dessings, grazing, collection of samples, and the trend of the serum magnesium levels in the grazing season during both experimental years have already been given in the articles referred to above, and are therefore only briefly considered here.

Experiments

In 1956 a grazing experiment was carried out with 16 milking cows on 6.09 hectares of permanent grassland divided up into 21 plots all of which were given the same amount of nitrogen but varying amounts of potash and phosphate (see table 1).

In 1957 the effect of varying amounts of potash and nitrogen was studied on the same experimental field which was now increased by 1.55 hectares. These 7.64 hectares were divided up into 21 plots each of which were given the same phosphate dressing in this year but varying amounts of potash and nitrogen (see table 2). The fertilizer treatments are designated by the corresponding symbols, the capitals referring to the heavier dressings.

Table 1 The 1956 experiment 6.09 hectare experimental pasture with 21 plots and 3 fertilizer treatments.

1956 Treatment	Area in hectares	Number of plots	Number of cows	Dressing in kg per hectare		
				N	P_2O_5	K_2O
Npk	1.53	7	4	230	30	50
NPk	1.53	7	4	230	260	50
NpK	3.03	7	8	230	30	450

Table 2 The 1957 experiment 7.64 hectare experimental pasture with 36 plots and 4 fertilizer treatments.

1957 Treatment	Area in hectares	Number of plots	Number of cows	Dressing in kg per hectare		
				N	P_2O_5	K_2O
nk	2.54	9	4	20	30	20
Nk	1.28	9	4	210	30	20
nK	2.54	9	4	20	30	200–300
NK	1.28	9	4	210	30	200–300

During both years the nitrogen dressing was distributed over the entire grazing periods and supplied in the form of nitro-chalk, except in 1956 when ammonium phoshpate was employed on the NPk plots, in which form the heavy phosphate dressing was also applied to these plots. On the other plots phosphorus was applied in the spring in the form of superphosphate. The potash dressing was mostly applied in the spring in the form of 60% muriate of potash.

Table 3 Plot Npk 1956

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with high nitrogen, low phosphate and low potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter							
			crude protein	K	Na	Ca	Mg	Cl	P	S
May 8	2.15	May 4- 8	22.1	2.62	0.10	0.61	0.16	0.96	0.42	0.32
11	2.30	4-11	21.9	2.81	0.11	0.59	0.16	1.08	0.42	0.34
15	1.95	8-15	21.4	2.78	0.14	0.54	0.16	1.22	0.41	0.36
18	1.95	11-18	19.8	2.47	0.15	0.51	0.16	1.17	0.39	0.34
22	1.90	15-22	16.7	2.25	0.17	0.51	0.16	1.09	0.37	0.32
25	2.35	18-25	15.3	2.17	0.27	0.54	0.17	1.06	0.36	0.31
29	2.35	22-29	17.9	2.42	0.22	0.59	0.19	1.16	0.41	0.34
June 1	2.40	25-June 1st	20.1	2.75	0.19	0.57	0.19	1.33	0.45	0.36
5	2.30	29-June 5th	20.2	2.74	0.19	0.49	0.19	1.43	0.43	0.36
12	2.20	June 5-12	19.5	2.70	0.21	0.49	0.18	1.34	0.38	0.35
19	2.05	12-19	17.9	3.04	0.16	0.52	0.19	1.45	0.42	0.33
26	2.25	19-26	19.9	2.74	0.21	0.50	0.18	1.39	0.40	0.36
July 3	*2.10 *)*	*26-July 3rd*	*13.3*	*2.91*	*0.19*	*0.50*	*0.14*	*1.48*	*0.37*	*0.24*
10	*2.35 *)*	*July 3-10*	*10.3*	*2.50*	*0.20*	*0.55*	*0.13*	*1.45*	*0.35*	*0.22*
17	2.35	10-17	14.7	2.57	0.26	0.54	0.16	1.48	0.38	0.30
24	2.15	17-24	19.0	2.16	0.30	0.51	0.16	1.33	0.42	0.31
31	2.10	24-31	17.3	2.61	0.18	0.54	0.17	1.24	0.41	0.31
Aug. 7	2.10	31-Aug. 7th	15.6	2.42	0.20	0.57	0.19	1.19	0.40	0.30
14	2.30	Aug. 7-14	18.6	2.63	0.22	0.53	0.17	1.47	0.41	0.31
21	*2.10 *)*	*14-21*	*17.6*	*3.29*	*0.16*	*0.57*	*0.16*	*1.64*	*0.46*	*0.29*
28	*2.30 *)*	*21-28*	*17.1*	*3.16*	*0.20*	*0.56*	*0.16*	*1.73*	*0.45*	*0.27*
Sept. 4	*2.30 *)*	*28-Sept. 4th*	*14.5*	*2.89*	*0.19*	*0.56*	*0.14*	*1.58*	*0.44*	*0.25*
11	*2.30 *)*	*Sept. 4-11*	*18.7*	*3.16*	*0.17*	*0.61*	*0.16*	*1.60*	*0.46*	*0.27*
18	2.35	11-18	18.9	2.84	0.28	0.54	0.17	1.42	0.43	0.28
25	1.90	18-25	18.7	2.21	0.39	0.56	0.17	1.60	0.41	0.30
Oct. 2	2.60	25-Oct. 2nd	18.4	2.57	0.27	0.60	0.20	1.27	0.43	0.36
9	2.35	Oct. 2- 9	16.2	2.49	0.24	0.54	0.18	1.17	0.42	0.30
16	2.00	9-16	14.5	2.44	0.20	0.55	0.15	1.25	0.40	0.30
23	2.05	16-23	18.2	2.28	0.27	0.53	0.17	1.32	0.39	0.35
26	2.33	19-26	21.9	2.47	0.33	0.49	0.15	1.45	0.44	0.35
Mean	2.20		18.5	2.55	0.22	0.54	0.17	1.29	0.41	0.33

*) In these periods all 16 cows were grazing at a non experimental pasture.

Grazing

The experiments lasted from the commencement to the end of the grazing period, viz. in 1956 from 4th May to 26th October and in 1957 from 23rd April to 24th October. Both in 1956 and 1957 there were two periods of shortage of grass on the experimental pastures. During these periods all experimental animals grazed together on a non-experimental pasture. The ages of the experimental animals varied from three to eight years and the milk production fluctuated around 17 to 25 kg per cow per day before the beginning of the experiment. After the respective plots had been grazed down all 16 cows were simultaneously transferred to the new plots, and these dates were always carefully noted so

Table 4 Plot NPk 1956

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with high nitrogen, high phosphate and low potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter							
			crude protein	K	Na	Ca	Mg	Cl	P	S
May 8	2.15	May 4- 8	21.5	2.59	0.10	0.64	0.16	0.97	0.48	0.36
11	2.15	4-11	21.8	2.71	0.10	0.61	0.16	1.02	0.47	0.37
15	1.55	8-15	20.8	2.70	0.13	0.51	0.16	1.13	0.45	0.36
18	2.00	11-18	19.2	2.57	0.15	0.47	0.16	1.18	0.43	0.34
22	1.80	15-22	16.5	2.43	0.17	0.46	0.16	1.17	0.40	0.30
25	2.50	18-25	14.9	2.20	0.21	0.51	0.16	1.11	0.38	0.29
29	2.40	22-29	17.5	2.44	0.20	0.55	0.18	1.13	0.45	0.33
June 1	2.40	25-June 1st	20.4	2.81	0.16	0.54	0.19	1.24	0.51	0.38
5	2.30	29-June 5th	21.7	2.81	0.16	0.48	0.19	1.38	0.51	0.38
12	2.10	June 5-12	19.7	2.75	0.19	0.46	0.19	1.38	0.42	0.35
19	2.20	12-19	17.3	2.76	0.23	0.54	0.18	1.39	0.47	0.34
26	2.30	19-26	19.7	2.94	0.15	0.47	0.17	1.35	0.48	0.35
July 3	*2.20 *)*	*26-July 3rd*	*13.4*	*2.91*	*0.18*	*0.49*	*0.14*	*1.47*	*0.38*	*0.25*
10	*2.55 *)*	*July 3-10*	*10.3*	*2.50*	*0.20*	*0.55*	*0.13*	*1.45*	*0.35*	*0.22*
17	2.50	10-17	13.8	2.46	0.23	0.52	0.15	1.38	0.44	0.28
24	1.85	17-24	18.2	2.32	0.30	0.47	0.17	1.34	0.50	0.32
31	1.90	24-31	16.3	2.85	0.16	0.46	0.17	1.30	0.48	0.31
Aug. 7	2.15	31-Aug. 7th	14.6	2.39	0.20	0.52	0.17	1.26	0.45	0.29
14	1.95	Aug 7-14	17.0	2.31	0.24	0.51	0.16	1.36	0.47	0.27
21	*2.45 *)*	*14-21*	*17.6*	*3.29*	*0.16*	*0.57*	*0.16*	*1.64*	*0.46*	*0.30*
28	*2.15 *)*	*21-28*	*17.1*	*3.15*	*0.20*	*0.56*	*0.16*	*1.73*	*0.45*	*0.27*
Sept. 4	*2.40 *)*	*28-Sept. 4th*	*14.5*	*2.89*	*0.19*	*0.56*	*0.14*	*1.58*	*0.44*	*0.25*
11	*2.30 *)*	*Sept. 4-11*	*18.7*	*3.16*	*0.17*	*0.61*	*0.16*	*1.60*	*0.46*	*0.27*
18	2.30	11-18	20.4	2.71	0.24	0.46	0.16	1.38	0.52	0.28
25	1.70	18-25	18.3	2.37	0.36	0.49	0.17	1.50	0.53	0.30
Oct. 2	2.55	25-Oct. 2nd	18.2	2.54	0.30	0.59	0.17	1.43	0.50	0.34
9	1.85	Oct. 2- 9	16.1	2.63	0.22	0.48	0.16	1.19	0.47	0.32
16	1.90	9-16	15.3	2.84	0.15	0.48	0.15	1.26	0.44	0.36
23	1.00	16-23	19.6	2.47	0.25	0.46	0.16	1.20	0.50	0.36
26	1.47	19-26	23.4	2.57	0.31	0.44	0.15	1.35	0.55	0.34
Mean	2.04		18.4	2.59	0.21	0.51	0.17	1.27	0.47	0.33

*) In these periods all 16 cows were grazing at a non experimental pasture.

that the duration of grazing in half-days of all plots is exactly known (see tables 3 to 9). During practically the entire grazing periods in both years the cows fed solely on grass and no supplementary feed was given. The only exception to this rule was during the period from 10th to 16th May 1957 when after the occurrence of six cases of hypomagnesaemic tetany all the other animals were given 50 grams of MgO per cow per day in the form of cakes.

During both years clover and herbs were reduced to negligible amounts by means of hormonal sprays. Hence the effect of the various dressings on the serum magnesium levels is only caused by changes in the chemical composition of herbage containing grasses only.

Table 5 Plot NpK 1956

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with high nitrogen, low phosphate and high potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter							
			crude protein	K	Na	Ca	Mg	Cl	P	S
May 8	1.98	May 4- 8	21.8	3.26	0.09	0.59	0.14	1.54	0.41	0.35
11	1.70	4-11	21.9	3.52	0.10	0.56	0.14	1.74	0.42	0.36
15	1.15	8-15	20.6	3.60	0.12	0.49	0.14	1.85	0.40	0.34
18	1.58	11-18	18.8	3.38	0.11	0.46	0.14	1.77	0.37	0.32
22	1.48	15-22	16.9	3.35	0.10	0.47	0.15	1.91	0.36	0.29
25	2.10	18-25	15.5	3.30	0.11	0.50	0.15	2.01	0.36	0.29
29	2.10	22-29	18.3	3.31	0.13	0.63	0.16	1.92	0.40	0.31
June 1	2.28	25-June 1st	21.0	3.51	0.13	0.53	0.17	1.95	0.45	0.35
5	2.03	29-June 5th	21.6	3.78	0.12	0.46	0.17	2.05	0.46	0.36
12	2.20	June 5-12	19.6	3.52	0.13	0.46	0.17	1.90	0.40	0.33
19	1.83	12-19	17.6	3.69	0.13	0.49	0.16	2.10	0.41	0.30
26	2.03	19-26	21.1	3.80	0.10	0.46	0.15	1.85	0.43	0.34
July 3	*2.13 *)*	*26-July 3rd*	*12.6*	*2.99*	*0.17*	*0.49*	*0.13*	*1.56*	*0.37*	*0.25*
10	*2.30 *)*	*July 3-10*	*10.3*	*2.50*	*0.20*	*0.55*	*0.13*	*1.45*	*0.35*	*0.22*
17	2.00	10-17	14.7	3.49	0.14	0.49	0.15	1.84	0.41	0.29
24	1.33	17-24	17.3	3.28	0.14	0.46	0.16	1.76	0.41	0.29
31	1.65	24-31	17.2	3.44	0.12	0.46	0.14	1.85	0.41	0.30
Aug. 7	1.83	31-Aug. 7th	14.7	3.10	0.12	0.48	0.13	1.71	0.38	0.27
14	1.73	Aug. 7-14	17.3	3.22	0.10	0.49	0.14	1.71	0.39	0.28
21	*1.93 *)*	*14-21*	*17.6*	*3.29*	*0.16*	*0.57*	*0.16*	*1.64*	*0.46*	*0.30*
28	*2.38 *)*	*21-28*	*17.1*	*3.16*	*0.20*	*0.56*	*0.16*	*1.73*	*0.45*	*0.27*
Sept. 4	*2.15 *)*	*28-Sept. 4th*	*14.5*	*2.89*	*0.19*	*0.56*	*0.14*	*1.58*	*0.44*	*0.25*
11	*2.30 *)*	*Sept. 4-11*	*18.7*	*3.16*	*0.17*	*0.61*	*0.16*	*1.60*	*0.46*	*0.27*
18	1.43	11-18	19.6	3.79	0.11	0.47	0.15	2.03	0.45	0.27
25	0.98	18-25	17.7	3.45	0.15	0.48	0.15	2.02	0.41	0.28
Oct. 2	1.55	25-Oct. 2nd	17.1	3.57	0.14	0.52	0.15	2.04	0.42	0.31
9	1.20	Oct. 2- 9	15.5	3.40	0.12	0.46	0.14	1.92	0.41	0.27
16	0.90	9-16	13.8	3.15	0.10	0.47	0.13	1.72	0.39	0.28
23	1.00	16-23	19.0	3.40	0.12	0.44	0.13	1.72	0.41	0.34
26	0.96	19-26	22.1	3.53	0.13	0.44	0.14	1.80	0.45	0.35
Mean	1.62		18.4	3.45	0.12	0.49	0.15	1.86	0.41	0.31

*) In these periods all 16 cows were grazing at a non experimental pasture.

SAMPLING

In 1956 a herbage sample was taken every three or four days from each plot grazed by cows, viz. three herbage samples on each sampling date. The non-experimental pastures were sampled during periods when the cows were not grazing on the experimental fields (see tables 3, 4 and 5). These samples were analysed for dry matter, crude protein, K, Na, Ca, Mg, Cl, P and S. In 1957 herbage samples were simultaneously taken from four plots immediately prior to pasturing the cows in these plots. During this year an average of four samples were taken every six days. These samples were analysed for dry matter, crude protein, K, Na, Ca and Mg (see tables 6, 7, 8 and 9).

Table 6 Plot nk 1957

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with low nitrogen and low potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter					
			dry matter	crude protein	K	Na	Ca	Mg
April 25	2.38	April 23-25	24.7	17.4	2.32	0.09	0.51	0.14
May 3	2.18	26-May 3rd	23.7	14.8	2.18	0.11	0.56	0.14
9	1.10	May 2- 9	20.4	15.1	2.15	0.15	0.56	0.13
16	2.28	9-16 1)	26.0	12.5	1.49	0.19	0.64	0.16
23	2.35	16-23	23.5	13.7	1.38	0.26	0.78	0.21
31	2.65	24-31	22.7	14.2	2.54	0.12	0.49	0.16
June 6	2.35	30-June 6th	23.8	12.2	2.20	0.13	0.45	0.15
13	2.20	June 6-13	22.7	11.5	1.75	0.19	0.46	0.14
20	2.28	13-20	25.7	12.8	1.57	0.26	0.61	0.20
27	2.80	20-27	21.6	14.0	2.40	0.19	0.56	0.18
July 4	2.58	27-July 4th	24.7	13.4	2.10	0.16	0.58	0.18
11	*2.58 *)*	*July 4-11*	*17.7*	*15.9*	*2.03*	*0.42*	*0.76*	*0.22*
18	*2.65 *)*	*11-18*	*16.2*	*16.5*	*2.84*	*0.24*	*0.80*	*0.22*
25	*3.10 *)*	*18-25*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
Aug. 1	*2.90 *)*	*25-Aug. 1st*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
8	2.75	Aug. 1- 8	24.3	13.7	1.55	0.42	0.75	0.27
15	2.60	8-15	18.9	13.5	1.64	0.34	0.76	0.28
22	2.78	15-22	21.1	13.1	2.80	0.16	0.52	0.19
29	2.68	22-29	20.5	13.4	2.84	0.10	0.46	0.18
			24.7	12.3	2.46	0.18	0.52	0.19
Sept. 5	2.60	29-Sept. 5th						
12	2.33	Sept. 5-12	20.5	13.2	2.28	0.15	0.49	0.18
19	*2.45 *)*	*12-19*	*17.4*	*15.3*	*2.85*	*0.24*	*0.54*	*0.16*
26	*2.13 *)*	no samples available						
Oct. 3	2.53	26-Oct. 3rd	19.5	16.8	1.85	0.44	0.56	0.17
10	2.58	Oct. 3-10	20.4	16.2	1.70	0.30	0.57	0.17
17	2.43	10-17	21.6	16.7	2.84	0.10	0.40	0.14
24	1.93	17-24	19.3	15.4	2.35	0.11	0.42	0.13
Mean	2.40		22.4	14.1	2.11	0.20	0.55	0.18

1) During this period the cows were dosed with 50 g MgO daily.

*) In these periods all 16 cows were grazing at a non experimental pasture.

In 1956 blood samples were taken twice a week from May tot June. From July to October 1956 and in 1957 the blood was invariably sampled once a week at the same day and hour. These samples, taken from the jugular vein, were analysed for magnesium, and in a number of 1956 samples for calcium and phosphorus as well. The sampling dates are given in the first column of tables 3 to 9. The second column shows the mean serum magnesium levels in the cows on the plots concerned.

In order to demonstrate the relationship existing between serum magnesium and the chemical composition of the herbage from the different fertilizer treat-

Table 7 Plot Nk 1957

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with high nitrogen and low potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter					
			dry matter	crude protein	K	Na	Ca	Mg
April 25	2.25	April 23-25	22.2	22.4	2.44	0.11	0.58	0.14
May 3	1.90	26-May 3rd	21.2	19.2	2.33	0.13	0.64	0.16
9	1.00	May 2- 9	17.9	19.2	2.57	0.18	0.56	0.14
16	2.15	9-16 [1])	22.2	16.4	1.44	0.22	0.66	0.16
23	2.20	16-23	20.1	17.0	1.19	0.32	0.88	0.24
31	2.55	24-31	19.4	17.9	2.76	0.51	0.54	0.18
June 6	2.33	30-June 6th	20.7	16.7	2.26	0.22	0.53	0.17
13	1.70	June 6-13	19.3	16.9	2.16	0.33	0.46	0.17
20	1.85	13-20	21.0	17.2	1.44	0.35	0.74	0.24
27	2.63	20-27	20.4	18.0	2.52	0.23	0.61	0.21
July 4	2.30	27-July 4th	21.1	18.0	2.05	0.27	0.63	0.22
11	*2.55 *)*	*July 4-11*	*17.4*	*16.3*	*2.01*	*0.43*	*0.76*	*0.22*
18	*2.60 *)*	*11-18*	*16.2*	*16.5*	*2.84*	*0.24*	*0.80*	*0.22*
25	*3.23 *)*	*18-25*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
Aug. 1	*2.80 *)*	*25-Aug. 1st*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
8	2.68	Aug. 1- 8	21.9	17.1	1.00	0.53	0.83	0.29
15	2.40	8-15	17.2	15.9	1.34	0.55	0.74	0.27
22	2.40	15-22	19.4	15.0	3.02	0.24	0.53	0.20
29	1.83	22-29	19.1	14.6	2.49	0.21	0.56	0.19
Sept. 5	2.18	29-Sept. 5th	21.5	16.5	2.13	0.36	0.59	0.23
12	1.70	Sept. 5-12	18.3	18.7	2.63	0.25	0.54	0.21
19	*2.30 *)*	*12-19*	*17.3*	*16.0*	*2.93*	*0.24*	*0.54*	*0.16*
26	*1.87 *)*	no samples available						
Oct. 3	2.13	26-Oct. 3rd	17.6	20.4	1.55	0.65	0.63	0.21
10	2.07	Oct. 3-10	18.3	19.9	1.73	0.50	0.60	0.20
17	2.23	10-17	18.8	20.8	3.08	0.20	0.45	0.16
24	1.97	17-24	16.5	18.8	2.62	0.26	0.47	0.16
Mean	2.12		19.7	17.9	2.13	0.30	0.61	0.20

*) In these periods all 16 cows were grazing at a non experimental pasture.

[1]) During this period the cows were dosed with 50 g MgO daily.

ments, the average composition of the herbage was calculated for weekly periods terminating on the day previous to blood sampling. These average values are weighted averages calculated from data on the duration of grazing per plot and the sampling date. Tables 3 to 9 list these data for each week, the third column showing the week to which the average after it relates. This use of averages for weekly periods is due to the fact that the serum magnesium levels may change from very low to high in the same week and vice versa, according to circumstances.

For the interpretation of the tables it should be explained that table 3 states

Table 8 Plot nK 1957

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with low nitrogen and high potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter					
			dry matter	crude protein	K	Na	Ca	Mg
April 25	1.75	April 23-25	23.9	15.4	3.09	0.07	0.56	0.12
May 3	0.58	26-May 3rd	21.0	13.3	3.05	0.08	0.56	0.12
9	0.93	May 2- 9	19.7	14.6	2.81	0.09	0.53	0.12
16	2.43	9-16 1)	22.8	13.5	2.91	0.08	0.49	0.12
23	2.03	16-23	23.1	12.5	2.66	0.10	0.59	0.14
31	2.38	24-31	22.3	12.5	3.01	0.07	0.46	0.13
June 6	2.13	30-June 6th	24.5	10.0	2.67	0.06	0.42	0.13
13	1.80	June 6-13	24.1	10.6	2.47	0.07	0.44	0.12
20	1.95	13-20	23.2	13.2	2.89	0.09	0.51	0.14
27	2.25	20-27	24.7	10.8	2.79	0.07	0.48	0.12
July 4	2.43	27-July 4th	25.0	11.8	2.70	0.08	0.53	0.15
11	*2.58* *)	*July 4-11*	*17.5*	*15.9*	*2.13*	*0.41*	*0.75*	*0.22*
18	*2.50* *)	*11-18*	*16.2*	*16.5*	*2.84*	*0.24*	*0.80*	*0.22*
25	*2.93* *)	*18-25*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
Aug. 1	*2.80* *)	*25-Aug. 1st*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
8	2.70	Aug. 1- 8	23.1	13.9	2.85	0.18	0.64	0.19
15	2.60	8-15	18.4	13.1	2.91	0.12	0.61	0.17
22	2.53	15-22	21.4	12.5	3.10	0.06	0.48	0.14
29	2.08	22-29	20.8	12.4	2.93	0.07	0.49	0.16
Sept. 5	2.10	29-Sept. 5th	23.3	12.1	3.02	0.10	0.49	0.14
12	1.90	Sept. 5-12	20.5	14.8	3.01	0.07	0.41	0.13
19	*2.23* *)	*12-19*	*17.5*	*15.6*	*2.93*	*0.23*	*0.53*	*0.16*
26	*2.13* *)	no samples available						
Oct. 3	1.80	26-Oct. 3rd	19.5	16.1	3.10	0.12	0.41	0.14
10	1.65	Oct. 3-10	18.2	16.7	3.24	0.10	0.41	0.14
17	1.25	10-17	22.4	15.9	2.99	0.07	0.38	0.13
24	0.75	17-24	20.3	14.8	2.62	0.07	0.38	0.11
Mean	1.91		22.0	13.4	2.90	0.09	0.49	0.14

*) In these periods all 16 cows were grazing at a non experimental pasture.

1) During this period the cows were dosed with 50 g MgO daily.

that on 11th May blood samples were taken of the experimental animals on the Npk plots and that the average serum magnesium level of this group at that date was 2.30 mg/100 ml.

For seven days preceding this sampling date, i.e. from 4th to 11th May, these cows consumed grass of the following average composition : 21.9 % crude protein, 2.81 % K, 0.11 % Na, 0.16 % Mg, etc. Below the tables are listed that average values throughout the experimental period during the year in question, the italicised data relating to the non-experimental pastures not being included.

Table 9 Plot NK 1957

Composition of herbage and serum magnesium concentrations in cows in weekly grazing periods on plots with high nitrogen and high potassium dressings

Date of blood sampling	Mg in blood-serum mg/100 ml	Grazing period	Composition of herbage in percentages of dry matter					
			dry matter	crude protein	K	Na	Ca	Mg
April 25	1.68	April 23-25	22.7	19.6	3.27	0.06	0.55	0.13
May 3	0.53	26-May 3rd	18.8	20.4	3.59	0.07	0.54	0.13
9	0.68	May 2- 9	17.4	18.9	3.06	0.08	0.49	0.14
16	2.20	9-16 1)	20.3	16.9	2.99	0.10	0.54	0.14
23	1.50	16-23	18.7	16.5	2.95	0.15	0.64	0.16
31	1.55	24-31	17.6	19.5	3.83	0.09	0.50	0.15
June 6	1.58	30-June 6th	19.9	14.2	3.27	0.09	0.46	0.14
13	1.08	June 6-13	19.9	14.2	3.13	0.08	0.48	0.13
20	1.65	13-20	18.8	16.9	3.10	0.17	0.59	0.17
27	1.75	20-27	21.4	14.7	3.07	0.11	0.54	0.15
July 4	2.03	27-July 4th	19.7	19.3	3.34	0.11	0.55	0.17
11	*2.35 *)*	*July 4-11*	*17.1*	*16.4*	*2.13*	*0.41*	*0.75*	*0.22*
18	*2.33 *)*	*11-18*	*16.2*	*16.5*	*2.84*	*0.24*	*0.80*	*0.22*
25	*2.98 *)*	*18-25*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
Aug. 1	*2.70 *)*	*25-Aug. 1st*	*16.8*	*17.4*	*3.14*	*0.24*	*0.72*	*0.22*
8	2.63	Aug. 1- 8	20.2	15.6	2.51	0.33	0.67	0.23
15	2.50	8-15	16.2	14.5	2.83	0.25	0.60	0.19
22	2.25	15-22	18.2	14.2	3.63	0.11	0.46	0.17
29	1.80	22-29	18.0	14.3	3.41	0.10	0.48	0.16
Sept. 5	1.60	29-Sept. 5th	19.0	16.6	3.67	0.12	0.47	0.18
12	1.48	Sept. 5-12	17.5	18.6	3.54	0.10	0.48	0.18
19	*2.33 *)*	*12-19*	*17.3*	*15.9*	*2.97*	*0.24*	*0.54*	*0.16*
26	*2.00 *)*	no samples available						
Oct. 3	1.37	26-Oct. 3rd	17.5	18.6	3.63	0.13	0.44	0.16
10	0.87	Oct. 3-10	16.6	19.2	3.57	0.12	0.44	0.15
17	1.00	10-17	18.4	19.4	3.55	0.09	0.39	0.14
24	0.63	17-24	17.1	17.9	3.42	0.08	0.41	0.14
Mean	1.54		18.8	17.1	3.30	0.12	0.51	0.16

*) In these periods all 16 cows were grazing at a non experimental pasture.

1) During this period the cows were dosed with 50 g MgO daily.

Fertilizer treatment and chemical composition of herbage

In this section attention is chiefly paid to crude protein, potassium and magnesium and the effect of the various dressings on these substances. Other elements are only briefly referred to as mean values. For fuller information on the effect of fertilizer treatment on the mineral composition of herbage the reader is referred to articles by Dijkshoorn (1957) (1957) (1958) (1958) (1959) and Said (1959).

Tables 10 and 11 summarise the average compositions of the herbage for the entire season during both years.

Table 10 Average herbage composition as a percentage of the dry matter of plots with different fertilizer treatments in 1956 and 1957.

1956 Treatment	Crude protein	K	Na	Ca	Mg	Cl	P	S
Npk	18.5	2.55	0.22	0.54	0.17	1.29	0.41	0.33
NPk	18.4	2.59	0.21	0.51	0.17	1.27	0.47	0.33
NpK	18.4	3.45	0.12	0.49	0.15	1.86	0.41	0.31

Table 11.

1957 Treatment	Crude protein	K	Na	Ca	Mg
nk	14.1	2.11	0.20	0.55	0.18
Nk	17.9	2.13	0.30	0.61	0.20
nK	13.4	2.90	0.09	0.49	0.14
NK	17.1	3.30	0.12	0.51	0.16

Crude protein

Since in 1956 nitrogen was applied in a constant amount, the average crude protein content of the sward is substantially the same for the herbage of the three treatments (table 10, Fig. 1). In 1957 crude protein is higher in the herbage of the Nk and NK plots compared to the herbage in the nK and nk plots. The difference amounts to 25 to 30% of the lowest values. During the growing season crude protein varies from 10% to over 22% of the dry matter (Figs. 1 and 2). During both years the highest percentages occur at the beginning and end of the grazing period.

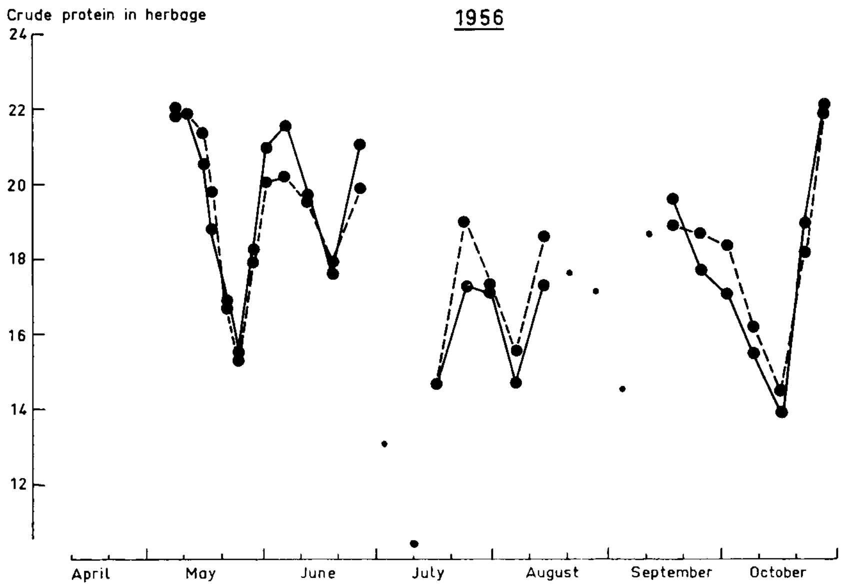
The marked variations in crude protein during the grazing period are no doubt due to the length of the grass during pasturing and to the fluctuations in the rate of growth.

Potassium

The data for both years illustrate very clearly that the application of a potassic fertilizer has the effect of greatly increasing the amount of potassium in the herbage. The increase in the potassium percentage resulting from the potash dressing is about 40% to 60% (see tables 10 and 11). In this case also the potassium values fluctuate exceedingly during the growing season, even to a considerably greater extent than crude protein (see Figs. 3 and 4). All individual values are in the range of from 0.90% K to 3.90% K.

The variations in the potassium contents of the herbage in the course of the growing season may be due to the same cause as the variations in crude protein. It should also be mentioned that the plots nearest the farm had higher potassium percentages in the herbage than those which were further away, the reason being that the soil close to the farm was considerably richer in potash in both the high and low potassium plots.

The potassium content of the herbage is also considerably influenced by nitrogenous fertilizer treatment. Table 11 and Fig. 4 show hat when the pasture is more heavily dressed with nitrogen there is a marked increase in the potassium content of the herbage on plots with a heavy potash dressing. An exception to



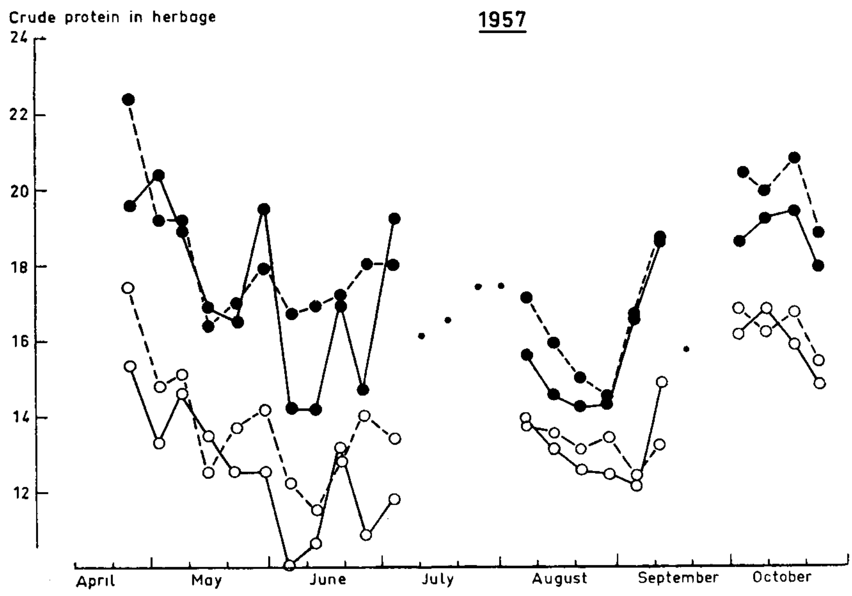


FIG. 1 AND 2 PERCENTAGES CRUDE PROTEIN IN HERBAGE OF PLOTS WITH DIFFERENT FERTILIZER TREATMENTS.

1956	1957
●——● NpK	●——● NK
●- - -● Npk	●- - -● Nk
	o——o nK
	o- - -o nk

..... data of non experimental pastures.

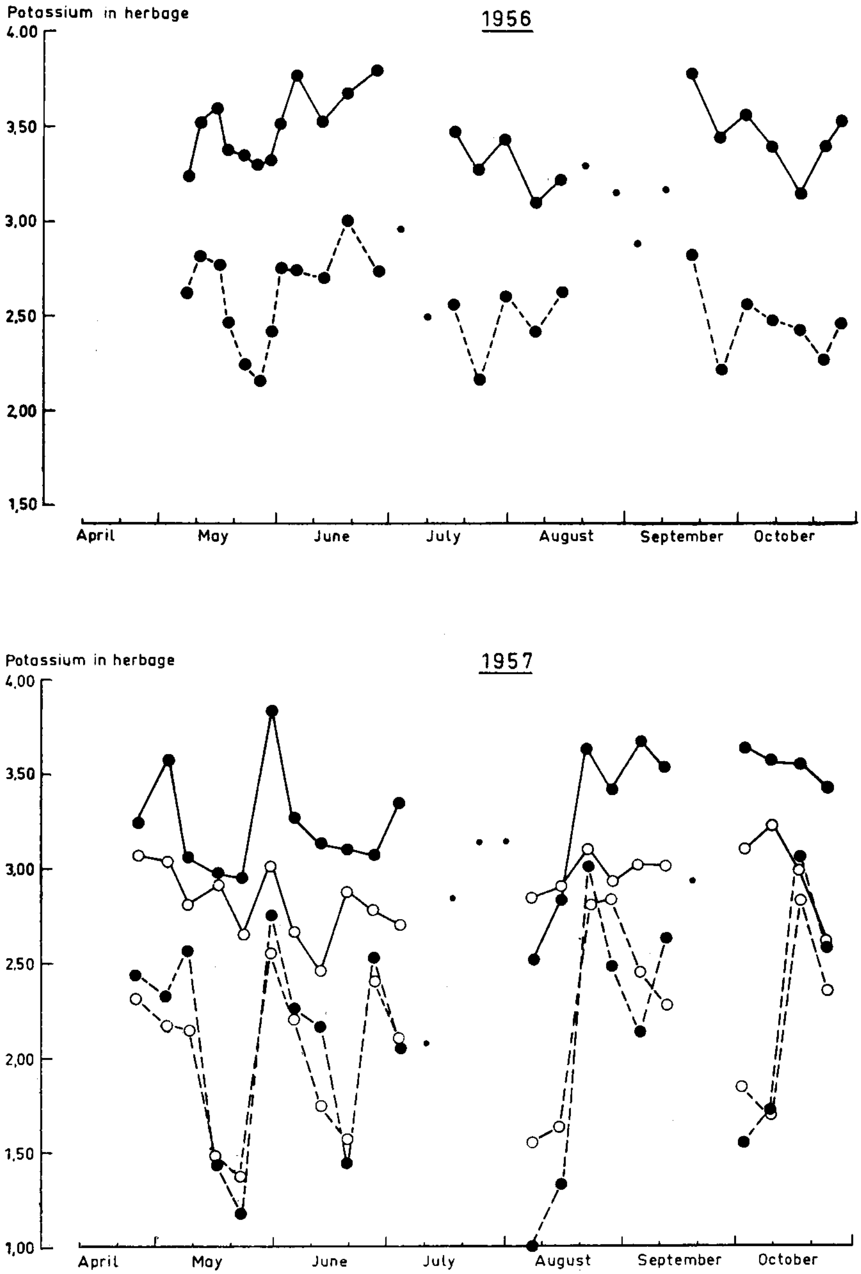


FIG. 3 AND 4 PERCENTAGES POTASSIUM IN HERBAGE OF PLOTS WITH DIFFERENT FERTILIZER TREATMENTS.

1956		1957	
●——●	NpK	●——●	NK
●- - -●	Npk	●- - -●	Nk
		o——o	nK
		o- - -o	nk

..... data of non experimental pastures.

this rule is formed by the pastures with the light potash dressing, as is shown by the potassium contents of the nK and NK plots and the nk and Nk plots in table 11 and Fig. 4.

The great differences in potassium contents between the herbage of the nK plots and the NK plots were reflected in each sampling during the growing season, this not being the case with the contents of the herbage of the nk and Nk plots. The increase in the potasium content of the herbage resulting from the nitrogen dressing is found to increase with an increasing potassium level in sward and soil. It seems that a low potash level may lead to a decrease in the potassium percentage of the sward when nitrogen is increased by a nitrogen dressing. A similar effect of nitrogen on potassium was also observed by SAID (1959) in his greenhouse experiments.

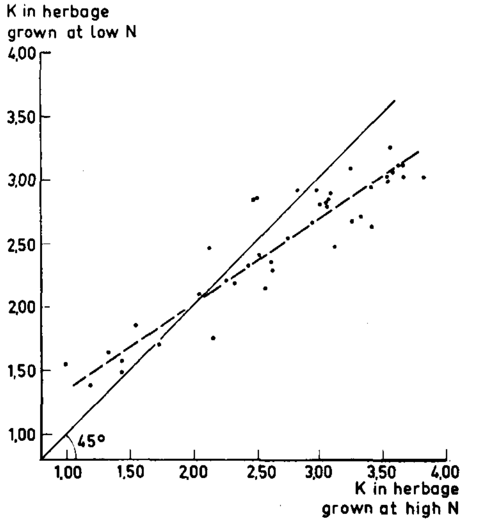


FIG. 5 EFFECT OF NITROGEN DRESSING ON THE POTASSIUM CONTENTS OF HERBAGE.

In Fig. 5 the potassium contents of the herbage of the plots with the light nitrogen dressing are plotted against the percentages of the herbage of the plots with a heavy nitrogen dressing. When the potassium content of the herbage exceeds 2.00% K, potassium increases as a result of an increase in nitrogen, viz. there has been a relatively greater increase in potassium uptake than in dry matter production. Below 2% K an increase in nitrogen is accompanied by a fall in potassium in the herbage. At such a low potash level the total potassium uptake is relatively less than the dry matter production, so that the potassium content in the herbage falls with an increasing nitrogen level.

SODIUM

A heavy potash dressing of the pasture leads to a considerable fall in the sodium content of the herbage. In 1956 the average sodium content of the herbage of the Npk plots was 0.22 %Na and of the NpK plots 0.12 % Na (table 10). The heavy phosphate dressing is not accompanied by lower sodium contents of the herbage. The antagonistic effect of potash on sodium can also be seen in table 11 in the 1957 figures, viz. in an average fall of from 0.20 % Na on the nk plots to 0.09 % Na on the nK plots, and from 0.30 % Na on the Nk plots to 0.12 % on the NK plots.

In the data relating to both years there is a 50 to 60 % decline in the sodium contents resulting from the application of heavy potash dressings. The nitrogen dressing causes a rise in the sodium contents and this rise is extremely dependent on the potassium level. On the nk and Nk plots with low potassium contents it varies from 0.20 % to 0.30 % Na, whereas on the nK and NK plots with high potassium contents the range is from 0.09 % to 0.12 % Na. This antagonistic effect is also reflected in the smaller increase in sodium accompanied by the greater increase in potassium between the nK and NK treatments as compared to the changes between nk and Nk (table 10).

Calcium and magnesium

Effects similar to those found in the case of sodium also occur with calcium and magnesium. Calcium and magnesium are also reduced by heavier potash dressings, whereas an increase in the nitrogen dressing results in an increase. The approximate decrease in the calcium content caused by the application of the heavy potash dressing is 10 to 15 % and that of the magnesium contents 15 to 20 % (tables 10 and 11). This decrease in the magnesium content of the herbage is shown in Fig. 6 in which the magnesium contents of the herbage of the plots with a low potassium content are plotted against the magnesium contents of the herbage of plots with a high potassium content.

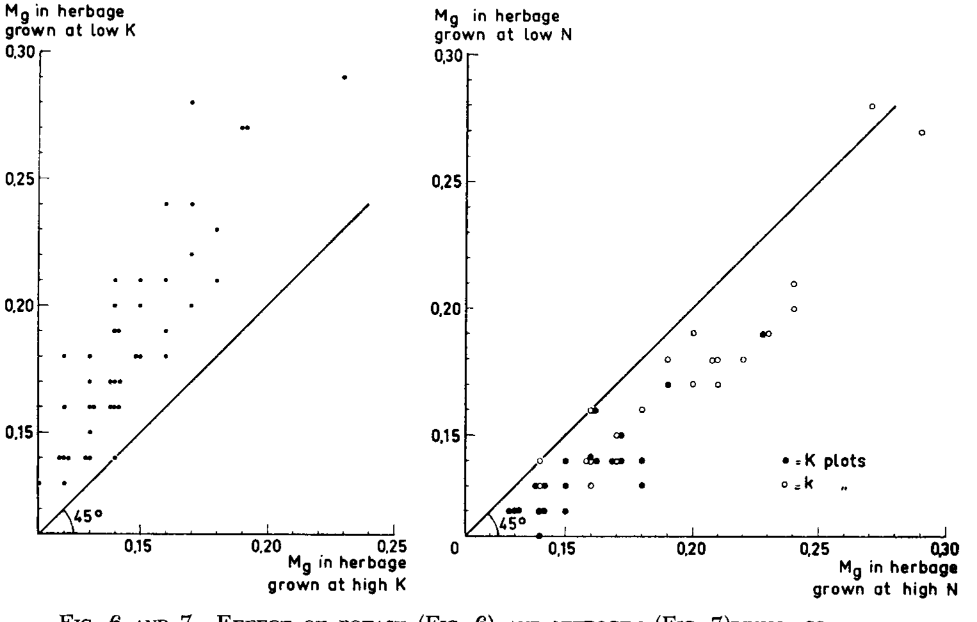


Fig. 6 and 7 Effect of potash (Fig. 6) and nitrogen (Fig. 7) dressings on the magnesium contents of herbage.

As will be demonstrated in a subsequent section, this fall in the magnesium content of the herbage resulting from a heavy potash dressing is an important factor in the magnesium feed of the animal. When the dry matter intake per animal per day is 15 kg with a magnesium content of 0.20% the daily magnesium intake is 30 grams Mg. When this magnesium content is reduced by 20% the daily magnesium intake is only 24 grams. Under the conditions prevailing in the Netherlands, where there are many farms on which far too much potassium is applied, a considerable improvement may be effected in the magnesium content of the herbage by avoiding excessive potash dressings. Fig. 7 shows that in a pasture consisting almost entirely of grasses the nitrogen dressing causes an increase in the magnesium contents of the herbage. If the nitrogen dressing has had no effect on the magnesium content of the herbage all points would be localised on the line making an angle of 45° with the abscis.

The composition of the herbage is influenced by the season as well as the dressing. Figs. 8 and 9 show that in 1956 and 1957 the lowest magnesium contents occurred in early spring and late autumn. The seasonal variations in magnesium are considerable. Higher magnesium contents are frequently found in summer, but this generally goes together with an increased percentage of clover and herbs compared to the spring and autumn. This clover effect is absent in the present experiments as there was hardly any clover in the herbage. What we see in possibly the effect of temperature on the composition DIJKSHOORN and 'T HART (1957) found in pot culture experiments that with temperature levels in the 20°–25° C range the herbage has a higher magnesium content than at 10° C. The fact that during the summer of 1956 (Fig. 8) the magnesium content was little higher than in the spring and autumn of 1957 (Fig. 9) might be due to the lower, summer temperatures in 1956.

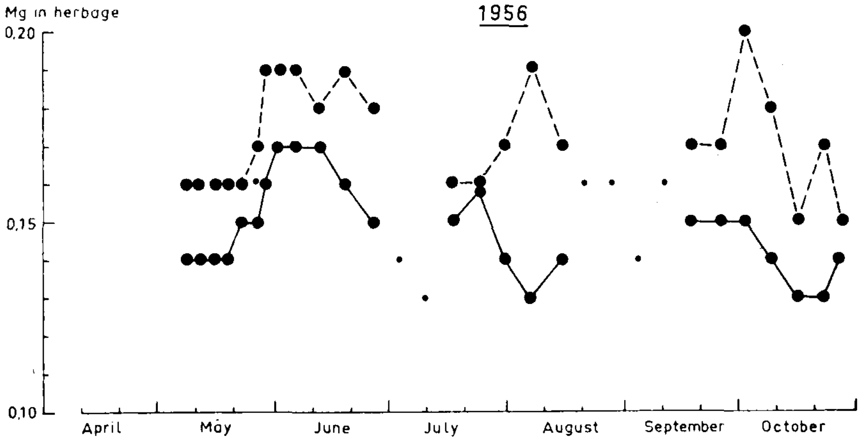
The considerably higher magnesium values of the herbage during the summer of 1957 go with higher serum magnesium levels in the cows as compared to the conditions found in the summer of 1956 (tables 12 and 13; KEMP 1958).

CHLORINE, PHOSPHATE AND SULPHATE

The most remarkable changes in chlorine, phosphorus and sulphur contents resulting from the different fertilizer treatments occur in chlorine in the herbage of the plots with high and low potassium contents, this being due to the fact that potassium was applied in the chloride form (see table 10). Phosphate is highest in the herbage of the NPk plots and sulphur is somewhat reduced in the herbage of the NpK plots; this may be due to the higher chlorine contents of the herbage of these plots. DIJKSHOORN (1959) has demonstrated that a reduction in sulphur leads to an increase in chlorine.

THE CHEMICAL COMPOSITION OF HERBAGE AND THE SERUM MAGNESIUM CONCENTRATIONS

Tables 12 and 13 summarise the serum magnesium levels of the experimental animals in both years throughout the grazing season. The serum magnesium trend, the differences occurring between the groups of animals and the incidence of hypomagnesaemic tetany have already been dealt with in full in previous articles. (KEMP, 1958, 1959).



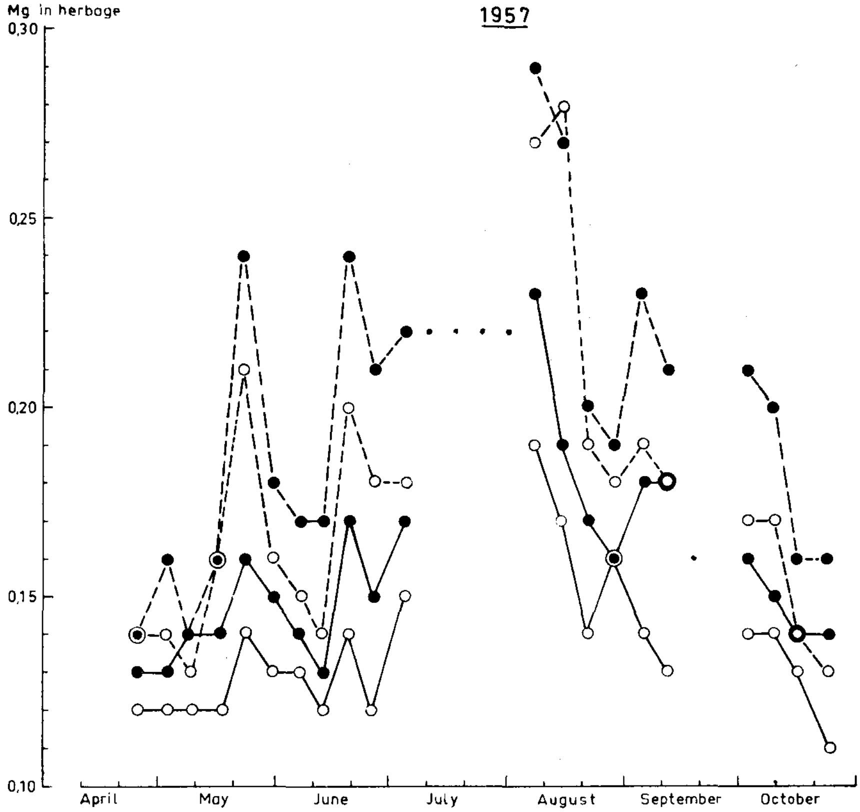


FIG. 8 AND 9 PERCENTAGES MAGNESIUM IN HERBAGE OF PLOTS WITH DIFFERENT FERTILIZER TREATMENTS.

1956		1957	
●——●	NpK	●——●	NK
●---●	Npk	●---●	Nk
		o——o	nK
		o---o	nk

..... data of non experimental pastures.

Table 12 Mean serum magnesium concentrations in milking cows over different periods of 1956 (table 12), and 1957 (table 13), on pastures with various fertilizer treatments.

1956 Treatment	In-doors	Exp. pastures 4/5-27/6	Outside the exp. 27/6-11/7	Exp. pastures 11/7-14/8	Outside the exp. 14/8-11/9	Exp. pastures 11/9-26/10	In-doors
Npk	2.51	2.18	2.18	2.20	2.25	2.24	2.28
NPk	2.50	2.16	2.38	2.07	2.33	1.80	2.30
NpK	2.53	1.86	2.22	1.71	2.19	1.12	2.13

Table 13.

1957 Treatment	In-doors	Exp. pastures 23/4-4/5	Exp. pastures 17/5-4/7	Outside the exp. 4/7-1/8	Exp. pastures 1/8-12/9	Outside the exp. 12/9-25/9	Exp. pastures 25/9-24/10	In-doors
nk	2.52	2.28	2.45	2.81	2.62	2.29	2.36	2.20
Nk	2.48	2.08	2.21	2.80	2.20	2.09	2.10	2.15
nK	2.40	1.16	2.14	2.70	2.32	2.18	1.36	1.98
NK	2.46	1.04	1.59	2.60	2.04	2.17	0.97	2.10

During the first two weeks of the grazing period in 1957 six cows suffered from hypomagnesaemic tetany, i.e. four on the nK plots and two on the NK plots. The differences in serum magnesium levels in cows on different plots are very striking. The greatest differences occurred in the spring and autumn, and the lowest values were invariably found on plots with heavy nitrogen and potash dressings; on the other hand the highest values were found on plots which had only been given a light nitrogen and potash dressing. An increase in the potash and nitrogen dressings both separately and combined caused a distinct drop in the serum magnesium levels. The fact that the mean serum magnesium levels between the groups of animals showed little or no difference during the "outside the experiment" and "indoors" periods proves that the very great differences occasionally found in the periods on the experimental pastures were the result of the different fertilizer treatments of these pastures.

In the literature there is little agreement on the question as to whether the magnesium content of the herbage has an affect on the incidence of hypomagnesaemic tetany. There are some workers who consider the magnesium content of the herbage to be fairly unimportant, and others who believe that the amount of magnesium ingested with the feed is an important factor. Experiments by CUNNINGHAM (1934), ALLCROFT and GREEN (1938), ALLCROFT, W. M. (1947), BREIREM (1949), ENDER et al. (1948), ALLCROFT, R. (1953) and KEMP (1959) have shown that oral administration of supplementary magnesium is able to prevent a fall in the serum magnesium level or to raise low levels. STEWART (1953), REITH (1954), BARTLETT (1954), PARR and ALLCROFT (1957) and SMYTH et al. (1958) have also demonstrated that an increase in the magnesium content of the herbage results in higher serum magnesium levels in the grazing animals.

The present results would suggest the existence of a relationship between the magnesium content of the herbage and the serum magnesium concentrations. The heavy potash dressing applied to the NpK plots in 1956 led to a steep decline in both serum magnesium and magnesium in the herbage (table 12, Fig. 8). In 1957 the serum magnesium levels during spring and autumn were considerably lower than during summer, and this went with a lower magnesium content in the sward during spring and autumn as compared to summertime conditions (table 13).

Serum magnesium on the NK and nK plots during the experimental periods was also considerably lower than on the Nk and nk plots (table 13), and the same is true of the magnesium content of the sward (Fig. 9).

The fact that a nitrogen dressing increases the magnesium content of the pasture and decreases the serum magnesium level indicates that the incidence of hypomagnesaemia is not solely due to the magnesium content of the pasture. For instance, table 13 shows that the NK plots produce lower serum magnesium values than the nK plots, the differences being significant. But the magnesium contents of the herbage of the NK plots are significantly higher than those of the nK plots (Fig. 9). Hence in these two plots lower serum magnesium concentrations are found with higher magnesium contents of the herbage. This inverse relationship is also found in the data relating to the Nk and nk plots. The serum magnesium levels on the Nk plots are lower than those on the nk plots (table 13), whereas the magnesium contents of the herbage are higher in the first plots (Fig. 9).

Since these results show that when the pasture is given heavy dressings of potash and nitrogen either separately or combined there is a fall in the serum magnesium concentrations, the question arises as to what extent the great differences in potassium and nitrogen contents of the herbage are also correlated to the serum magnesium levels. In this connection it should be remembered that only concentrations in herbage and blood serum are considered and that we have no information on the actual magnesium intake of the animal.

The 1956 data show that the lower serum magnesium concentrations in the cows on the NpK plots compared to those on the Npk plots go with higher potassium contents of the herbage and equal amounts of crude protein (see tables 10 and 12 and Figs. 1 and 3).

This is also reflected in the serum magnesium levels in cows on the nk plots and those on the nK plots, as well as in cows on the Nk plots and NK plots (see tables 13 and 11 and Figs. 2 and 4). Here too the lower serum magnesium levels are associated with higher potassium contents of the herbage, the crude protein contents remaining substantially unchanged.

It is found that the serum magnesium concentration also falls when crude protein in the herbage is increased by a nitrogen dressing, and without an increase in the potassium content of the herbage. This is shown by the data relating to the nk and Nk plots, since on the Nk plots the serum magnesium concentrations are lower than on the nk plots (tables 13 and 11, Fig. 4). Crude protein in the herbage of the Nk plots is consistently higher than in the nk plots (Fig. 2), and the same is true of the magnesium contents of the herbage. But there is practically no difference in the potassium contents of the herbage.

From this evidence we may draw the following conclusion. When the pasture is given a heavier dressing of muriate of potash (the nitrogen dressing remaining the same) the magnesium content of the herbage is reduced, the crude protein is unchanged, and there is a considerable rise in the potassium content. The serum magnesium concentrations fall in such a case.

When heavier nitrogen dressings are applied combined with a heavy potash

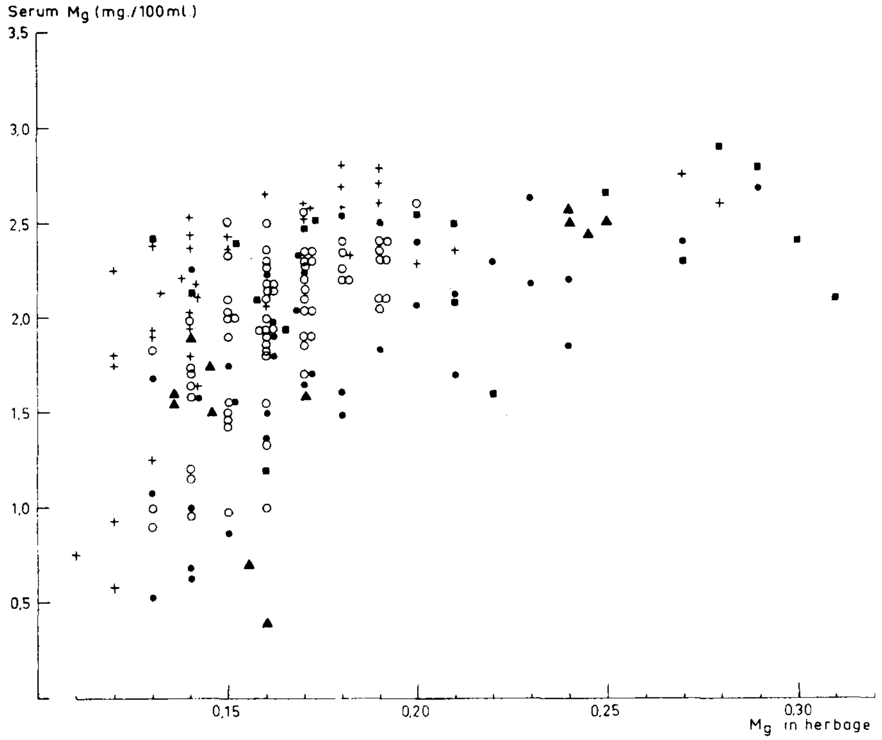


FIG. 10 RELATIONSHIP BETWEEN THE MAGNESIUM CONTENT OF THE HERBAGE AND THE SERUM MAGNESIUM CONCENTRATIONS IN MILKING COWS ON PASTURES WITH DIFFERENT FERTILIZER TREATMENTS.

o = 1956
\+ = 1957 nK and nk plots
• = 1957 NK and Nk plots
▲ Data of SMYTH, et al., 1958
■ Data of PARR and ALLCROFT, R., 1957

dressing there is also a fall in the serum magnesium concentrations, but the magnesium contents of the herbage rise, as do also the potassium and crude protein percentages. When a heavier nitrogen dressing is applied together with a very light potash dressing (with potash contents of the herbage lower than 2.0% K of the dry matter; see Fig. 5) the magnesium content of the herbage is increased as is also the crude protein, and potassium remains unchanged. In this case also there is a drop in the serum magnesium levels. The highest serum magnesium levels are found when there is a low potassium and nitrogen level in the herbage, resulting from a moderate dressing of the pasture with nitrogen and potassium.

It is important that we should now subject these conclusions to closer inspection, taking into consideration the relationship existing between the magnesium content of the herbage and the serum magnesium.

Figure 10 is assembled from data taken from tables 3 to 9 and some data from the literature. In this figure the mean serum magnesium concentrations of a group of cows are plotted against the magnesium percentages in the herbage during the week preceding blood sampling.

Low serum magnesium levels only occur when the magnesium contents of the herbage are low as well; the correlation between these two is significantly

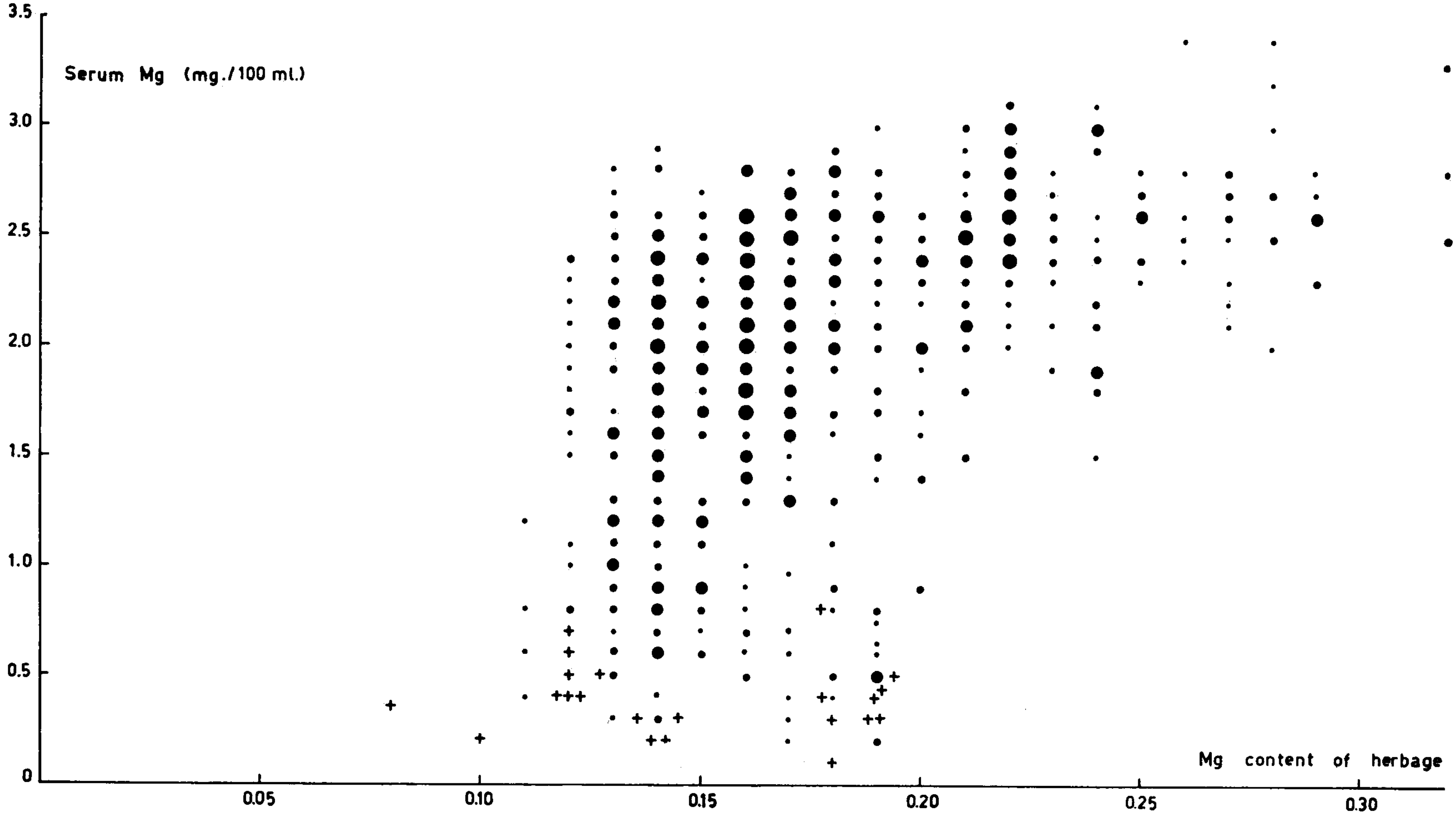


FIG. 11 RELATIONSHIP BETWEEN THE MAGNESIUM CONTENT OF THE HERBAGE AND THE SERUM MAGNESIUM CONCENTRATIONS IN 822 MILKING COWS OF WHICH 23 WERE SUFFERING FROM HYPOMAGNESAEMIC TETANY.

+ = with clinical symptoms.

positive. The data of PARR and ALLCROFT (1957) and SMYTH et al. (1958) are also in complete agreement with this pattern. The high magnesium contents of the herbage reached by these writers by the application of heavy magnesium dressings result in a marked increase in the serum magnesium concentrations. It is noticeable, however, that when the magnesium contents of the herbage are low the serum magnesium levels may be either very low or normal. Since under the conditions prevailing in the Netherlands the magnesium content of the herbage in the spring and autumn in particular is mostly lower than 0.20% Mg in dry matter, it is important that we should know the cause of this spread in serum magnesium levels.

Instead of the mean serum magnesium levels per group of cows, shown in Fig. 10, in Fig. 11 all individual serum magnesium concentrations per animal are plotted against the magnesium content of the herbage. This figure includes both the present data and data obtained by H. VOGELZANG of the State Agricultural Extension Service, Sneek, from a number of farms in Friesland as well as a number in the province of Utrecht. Thus the figure comprises the serum magnesium levels of 822 milking cows, 23 of which showed clinical symptoms of hypomagnesaemic tetany. As it was impossible to show all these separate dots in the figure, dots of different sizes were drawn, the number of observations per dot equalling the square of the diameter of the dot in mm. Thus a dot having a diameter of 4 mm represents 16 separate observations.

Clinical symptoms of hypomagnesaemic tetany only occured when the serum magnesium level was lower than 1.0 Mg/100 ml. This level confirms SJOLLEMA's (1931) findings. But here again it was found that not all animals having very low serum magnesium levels showed clinical symptoms of hypomagnesaemic tetany.

The low serum magnesium values solely occur with magnesium contents of the herbage lower than 0.20% Mg. It is noticeable that when the magnesium contents of the herbage exceed 0.20% Mg the serum magnesium level is never lower than 1.5 mg Mg/100 ml, while above this magnesium content of the herbage the serum magnesium levels are mostly within the normal range.

This evidence corroborates FRENS' (1950) estimate of the magnesium requirements of cows. KEMP and 'T HART's (1957) data relating to a large number of farms also demonstrate the absence of hypomagnesaemic tetany when the magnesium contents of the herbage exceed 0.20% Mg.

Fig. 11 also shows that below 0.20% Mg the serum magnesium levels may also reach normal values. The question arises as to whether these variations are connected with milk production. However, the data did not reveal any relationship between the daily milk yield and the serum magnesium concentrations, so that it is unlikely that the spread of serum magnesium levels with equal magnesium contents of the herbage is caused by differences in milk production. This is also shown by the results obtained by BARTLETT et al. (1957) and HVIDSTEN et al. 1959). Nor is it necessary for a high-yielding cow to be more susceptible to hypomagnesaemia than a low-yielding animal, since the herbage intake will increase with increasing milk production.

Other factors inherent in the quality of the herbage may influence the daily intake and the utilisation of herbage magnesium.

A full statistical treatment of these data has not yet been completed, but it has been found that there is not only a signifcantly positive correlation between herbage magnesium and the serum magnesium concentrations, but also a signifcant negative correlation between herbage potassium and serum magnesium, and between crude protein in herbage and serum magnesium.

Correlation between :	Correlation coefficient	Confidence limits (P = 0.01)
Magnesium in herbage and serum magnesium	+ 0.47	0.32 and 0.49
Potassium in herbage and serum magnesium	— 0.37	−0.52 and −0.20
Crude protein in herbage and serum magnesium	— 0.22	−0.38 and −0.04

The negative correlations between crude protein in herbage and serum magnesium, and between potassium in herbage and serum magnesium are partial correlations, the effect of potassium and crude protein being eliminated.

The variations in potassium and crude protein contents of the herbage with the corresponding serum magnesium levels are shown in Fig. 12. All dots in Fig. 11 lie inside the two lines specified in Fig. 12.

In the range of herbage magnesium below 0.20 % the lower serum magnesium levels are associated with higher percentages of crude protein and potassium in the herbage than is the case with the higher serum magnesium levels. Moreover when the serum magnesium concentrations are low the herbage contents of potassium and crude protein are highest with the highest herbage magnesium values and lowest with the lowest herbage magnesium values.

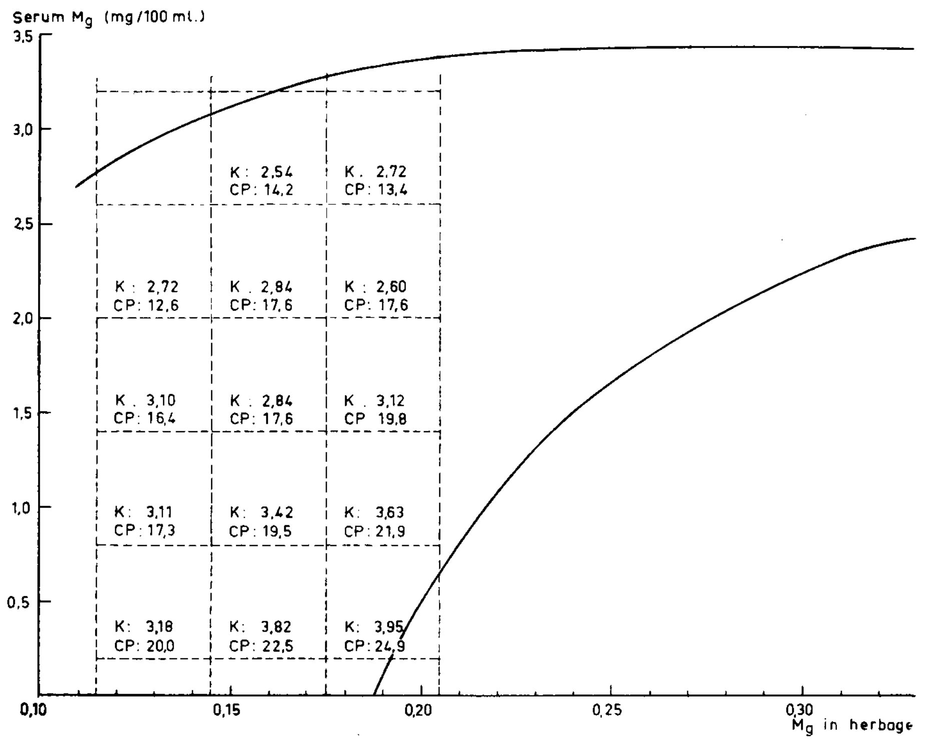


FIG. 12 RELATIONSHIP BETWEEN THE PERCENTAGES MAGNESIUM, POTASSIUM AND CRUDE PROTEIN IN HERBAGE AND THE SERUM MAGNESIUM CONCENTRATIONS.

This implies that when the serum magnesium levels are low the percentages of potassium and crude protein in herbage are not always high, this only being the case when the herbage magnesium values are higher.

There is an obvious explanation of the correlation between herbage magnesium and serum magnesium. The fact that an increase in the magnesium content of the herbage prevents a fall in the serum magnesium levels is in agreement with the results obtained in the above-mentioned studies on the effect of an oral administration of magnesium and an increase in herbage magnesium resulting from fertilizer treatment. The unfavourable effect exerted on the serum magnesium levels by a heavy potash dressing can now be partly explained, i.e. by the 15 to 20% reduction in herbage magnesium resulting from the increase in potassium.

The reason for the partial correlations between crude protein in herbage, serum magnesium and potassium in herbage and serum magnesium is less obvious. A possible explanation is that heavy dressings of potassium and nitrogen have an adverse effect on the herbage intake of the cows, resulting in a lower magnesium intake of herbage having a high content of crude protein and for potassium. In this connection we may refer to the results obtained by Breirem et al. (1949) who found that the increased incidence of hypomagnesaemic tetany could be accounted for by the low intake of magnesium, coupled with a low energy intake.

Since an accurate determination of the daily magnesium intake is impossible in grazing experiments no conclusion can be drawn on this matter.

In view of the literature data, and having regard to our own experiments, it would seem likely that the composition of the herbage has an effect on the animal's utilisation of magnesium. For instance, the rat experiments performed by Armtrong et al. (1952) (1953) and (1957) showed that the "availability" of calcium is lower in cocksfoot than in timothy and perennial rye grass. The grasses as a whole were found to be inferior to both legumes and herbs in respect of calcium "availability". Rook et al. (1958) and Kemp et al. (unpublished data) have demonstrated by means of balance experiments with milking cows fed on freshly cut herbage that about 70 to 90% of the daily ingested herbage magnesium is excreted in the faeces. The remainder, some 30 to 10%, corresponds to the "available" magnesium. The variation in "availability" is so great that when there is a low daily magnesium intake it may be an important factor in the incidence or non-incidence of hypomagnesaemia. In addition to the utilisation of the ingested magnesium varying from one animal to another, there are indications that the treatment of pasture with potash and/or nitrogen may have an adverse effect on the "availability" of magnesium in herbage. This would at least partly explain the negative correlations between the percentages of potassium and crude protein in herbage and the serum magnesium levels.

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