GRASS TETANY IN GRAZING MILKING COWS [1])

A. KEMP and M. L. 'T HART [2])
Central Institute for Agricultural Research, Wageningen

SUMMARY

1 Statistical investigation showed that a significant correlation exists between the incidence of grass tetany and the mean 24-hour temperature (Figs. 1 and 2). Two types of fluctuations may be distinguished in the frequency of tetany, viz. a seasonal fluctuation which shows a correlation with the mean temperature during the year, and superimposed on this a number of brief fluctuations showing a correlation with the daily changes in temperature.

The seasonal fluctuation is seen in the occurrence of the "grass tetany period" in spring and autumn when the temperature level is below about 14° C. During the warmer summer months there are practically no tetany cases. The brief fluctuations during these grass tetany periods are very closely correlated to the temperature fluctuations below the level of approximately 14° C.

About 5 days after a rise in temperature from a level below 14° C there is an increase in the number of tetany cases, whereas on an average of 5 days after a fall in temperature there is a fall in the number of cases. Thus during the brief fluctuations a time-lag of 5 days is to be noted between action (change in temperature) and reaction (number of tetany cases), and we associated this time-lag with a change in the mineral composition of the pasture brought about by the temperature.

2 Chemical examination of a large number of grass samples taken from pastures with and without tetany cases showed that the $\frac{K}{Ca + Mg}$ ratio in the grass is significantly correlated to the incidence of tetany (Fig. 3). When the value of this ratio is less than 2.2 there are very few tetany cases (0.77 % of 4658 head of cattle in the material investigated by us). But when the value rises beyond 2.2 the disorder occurs far more frequently (6.66 % of 1908 head of cattle).

3 On investigating the effect of temperature on the mineral composition of the pasture we found that both on an experimental field specially laid out for the purpose (Fig. 4) and in the two samples noted under 2 (Fig. 5), the pasture takes in more potassium when there is a rise in temperature during the spring tetany period (i.e. below the 14° C level). This increases the value of the $\frac{K}{Ca + Mg}$ ratio, as the Ca and Mg intakes remain practically constant. When the temperature falls the position is reversed.

Consistently low temperatures in the spring and autumn produce a higher $\frac{K}{Ca + Mg}$ ratio value than consistently high temperatures during summer.

4 These results favour the theory that the relationship between temperature and the incidence of tetany is correlated to the cationic composition of the herbage ingested by the animals.

INTRODUCTORY

Since 1954 we have been conducting an investigation into the incidence of grass tetany in dairy cattle, assisted by the Faculty of Veterinary Science of the University of Utrecht.

The investigation included some 750 farms on sandy or clayey soil at which veterinary medicine is practised by the above-mentioned faculty. Data concerning the incidence of the disorder on these farms has been assembled over many years.

[1]) Received for publication November 28, 1956.

[2]) At present Professor at the Agricultural University, Wageningen.

This valuable statistical material was made available to us, and after we had worked it up a number of interesting points came to light concerning the effect of weather conditions, and particularly the temperature, on the incidence of grass tetany. A closer study revealed that this effect might very possibly be largely accounted for by a change in the mineral composition of the herbage ingested by the animals.

This induced us to carry out a further investigation of the problem at the Central Institute of Agricultural Research by means of field trials and pot experiments. We also examined the relationship between the composition of the pasture at various farms and the incidence of grass tetany.

The following matters will be discussed below in the order indicated:

1 The relationship between weather conditions and the incidence of grass tetany in cattle. This part of the investigation has already been published in full elsewhere ('T HART and KEMP, 1956 a) so that it will only be necessary to give a brief summary here.
2 The effect of the chemical composition of pasture on the incidence of grass tetany.
3 The effect of temperature on the composition of the pasture in connection with the incidence of grass tetany.

1 THE RELATIONSHIP BETWEEN WEATHER CONDITIONS AND THE INCIDENCE OF GRASS TETANY IN CATTLE

This correlation was discovered after studying the statistics referred to above. Of the years covered, only those were selected in which at least 100 cases of tetany had occurred on the 750 farms observed, viz. 1931, 1932, 1935, 1944 and 1948 to 1954, or a total of 11 years in which there were 1146 tetany cases in the pasture, 940 occurring in the spring (chiefly in April and May) and 206 in the autumn (September, October and November).

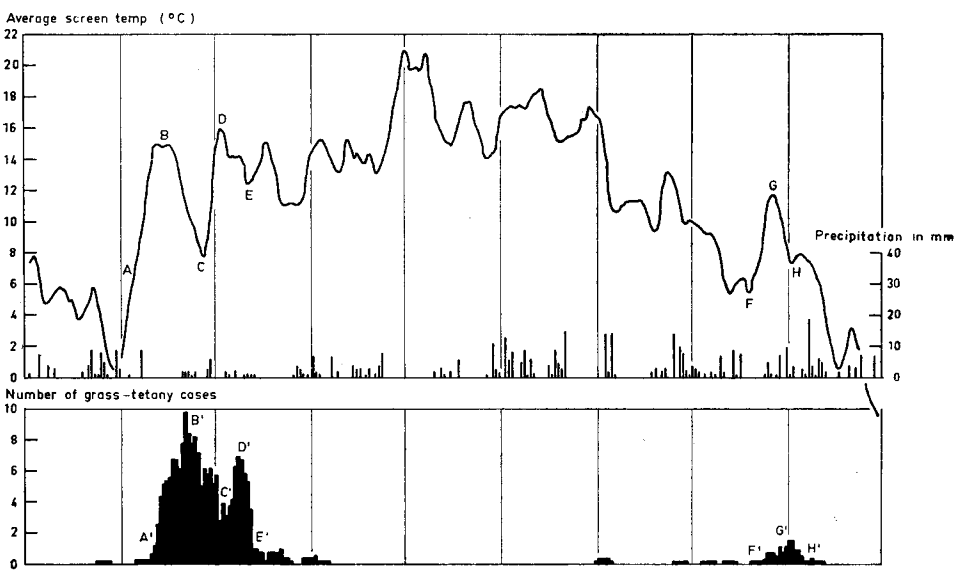

FIG. 1 LEVEL OF TEMPERATURE AND PRECIPITATION AND THE INCIDENCE OF GRASS TETANY IN 1952.

By way of example, Fig. 1 shows the distribution of the number of tetany cases in 1952 together with the mean 24-hour temperatures and the daily amount of precipitation. The values given for grass tetany and temperature are progressive averages per period of 5 days, noted on the third day.

In this case it is first of all found that the number of tetany cases decreases as the weather grows warmer, and this is a feature of all the 11 years under consideration. In general the rule is that there is little or no further occurrence of grass tetany when the mean 24-hour temperature per decade in the spring has risen to about 14° C. When the temperature falls below this level in the autumn there is a further outbreak of the disease. Consequently, the longer it takes for the temperature to rise above a level of about 14° C, the longer is the duration of the spring tetany period.

There is also evidence that a high degree of precipitation in summer and in autumn is accompanied by a greater number of tetany cases in this periods, this being particularly the case in 1954 and 1956.

Secondly, we believe it true to say that fluctuations in temperature below the 14° C level, viz. during the tetany periods in the spring and autumn, are correlated to the curve of its frequency. The statistical enquiry showed that the curve of this frequency follows the corresponding temperature with a lag (Fig. 1). After a rise in temperature from a level of less than 14° C mean 24-hour temperature the number of tetany cases increases, whereas after a fall in temperature the number is observed to decrease. The lower the level from which the rise in temperature occurs the greater is the increase.

In the case of every year studied this phenomenon occurs both in the spring and autumn, and the time-lag averages 5.1 days. As the temperature reaches a higher level the time-lag decreases. This is represented in Fig. 1 by the difference in time between A and A_1, B and B_1, etc.

Table 1 shows the number of cases in which a rise or fall in temperature is respectively followed by an increase or decrease in the frequency of grass tetany in the spring and autumn, a margin of 2 to 8 days being allowed for the time-lag.

Table 1 Relationship between a falling or rising temperature and an increase or decrease in the number of tetany cases.

Grass tetany \ Temperature	Rise	Fall
Increase	33	0
No change	3	2
Decrease	1	35

These figures show that in this case we have a reliable correlation. When a margin of 3 to 7 days is allowed for the time-lag there is no increase in the number of exceptions.

Fig. 2 shows the connection between the duration of the temperature fluctuations and the duration of the variations in the frequency of grass tetany. The duration of the successive changes in temperature is here plotted against the duration of the successive variations in the frequency of grass tetany. The last rise in temperature before the occurrence of the first peak in the frequency of grass tetany is taken as the first change in temperature. For the 11 years under consideration this was done in the spring and autumn during all grass tetany periods in their entirety.

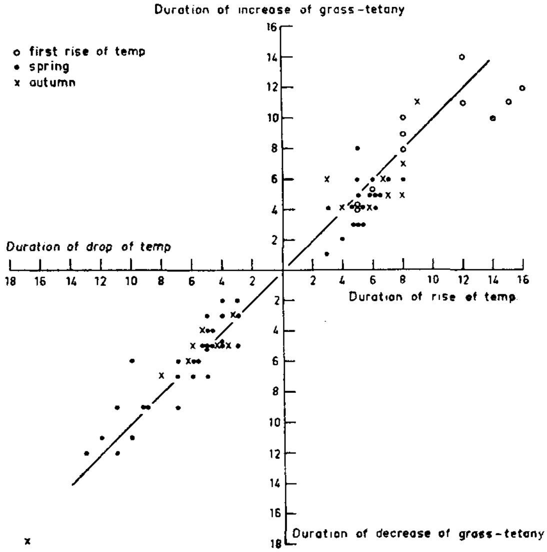

FIG. 2 RELATIONSHIP BETWEEN THE DURATION OF THE RISE OR FALL IN TEMPERATURE AND THE DURATION OF THE SUBSEQUENT INCREASE OR DECREASE IN GRASS TETANY (IN DAYS).

The correlation coefficient (r) of the first quadrant is 0.60 (Sr = 0.13), that of the third quadrant 0.92 (Sr = 0.024). The lines calculated in the first and third quadrants, according to the equations $y = 0.76x + 0.61$ and $y' = 0.95x' + 0.23$ respectively, do not differ significantly from the 45° line drawn in the figure. When the duration of the successive rises in temperature are plotted against the successive duration of the decreases in tetany, and the duration of the falls in temperature against the successive duration of the increases in tetany no correlation is found to exist.

It follows from the above that during years in which the temperature fluctuates only slightly below a level of 14° C there is a grass tetany frequency with one peak only. On the other hand, when there are great fluctuations of temperature below this level a frequency occurs which has several peaks, depending on the number of temperature peaks (see also Fig. 1).

ALLCROFT and GREEN (1938) and ALLCROFT (1947) found that the highest serum magnesium values occurred in periods of high temperature and when there had been little precipitation during the preceding months. Low magnesium levels were found at low temperatures and after much precipitation. The minimum serum magnesium levels were encountered from December to April and the maximum in August. The calcium values showed little variation. These observations were made on a large herd of cattle at pasture all the year round and only given supplementary fodder during periods of bad weather. As low blood magnesium is looked upon as the characteristic abnormality of grass tetany we may infer from this that the correlation we found between temperature levels and the incidence of grass tetany agrees with the above-mentioned relationship already found between temperature levels and the serum magnesium levels in the animals. ALLCROFT and GREEN were unable to investigate the effect of the temperature variations on the serum magnesium level because the blood samples were taken every one or two months.

With regard to what has been said above concerning the effect of temperature levels and fluctuations on the incidence of grass tetany, it is important to know whether these changed conditions have a direct effect on the animal, or whether they are to be described as an indirect effect, e.g. one caused by a change in the fodder ingested by the animal as a result of the temperature. INGLIS et al. (1954) assume an indirect relationship, stating that "the effect of climate on serum magnesium would appear to be indirect and to act through its influence on nutrition".

In order to be better informed on this subject it is necessary to have data on the composition of pastures with tetany cases and pastures without tetany cases and also to understand how their composition is influenced by temperature.

2 THE EFFECT OF THE CHEMICAL COMPOSITION OF PASTURE ON THE INCIDENCE OF GRASS TETANY IN DAIRY CATTLE

As stated in the introduction, the investigation is being carried out on 750 farms. 327 grass samples were taken in the spring of 1954 and 1955, chiefly during the first 5 weeks of the grazing period, and also in the autumn. These samples were collected both from farms where there is a regular occurrence of grass tetany among the dairy cattle, and from farms where the disorder has not occurred for the past 10 years. This sampling, which was carried out in several fields on each farm, always took place just before the animals had been turned out to grass on the field in question. The pasture was examined for crude protein, potassium, sodium, calcium, magnesium, chlorine, phosphorus and sulphur. In addition to collecting this sample material, the greatest possible number of grass tetany cases were visited within two days from the time of treatment by the veterinary surgeon. A grass and soil sample were taken from the pasture on which the animal in question had been grazing, and data were also collected on the fertilization, pasturing, the feeding of supplementary fodder, age of the animal, yield of milk, etc. The veterinary surgeon in attendance took a sample of blood from the animal and calcium, magnesium and phosphorus determinations were made on these samples.

On the basis of the blood analyses and the case-history prepared by the veterinary surgeon a final diagnosis was made of every case by Professor J. A. BEYERS of the Faculty of Veterinary Science of the University of Utrecht. Wherever the term "grass tetany" is employed hereinafter the reference is to hypomagnesæmia with more or less marked clinical symptoms.

Table 2 gives the average composition of 170 samples of pasture from 170 different fields which had been grazed in the spring of 1954 or 1955 and where no grass tetany had occurred during this period. During the grazing of these fields the cattle were given no supplementary feed in the form of pulp, potato residues or extra magnesium (NT).

This average composition is compared with that of 100 samples of pasture from fields grazed during the same period where one or more cases of grass tetany had occurred per field. In this case also no supplementary fodder was given in the form of the products mentioned above. In this group there were 163 cases of grass tetany (T). The third group gives the average composition of 57 samples of herbage taken from fields in which there were no cases of grass tetany, but where the animals had been given supplementary fodder in the form of pulp, potato residues or extra magnesium (NT + S). These samples were chiefly taken from farms on which there had been a regular occurrence of grass tetany in preceding years.

The separate contents are shown as percentages of the dry matter, while the ratio $\frac{K}{Ca + Mg}$ was calculated from the contents expressed in milliequivalents per kg of dry matter.

Table 2 Average composition of herbage from pastures with and without cases of grass tetany.

	Number of samples	re	K_2O	Na_2O	CaO	MgO	P_2O_5	Cl	SO_4	$\frac{K}{Ca + Mg}$
NT	170	23.8	3.65	0.34	0.89	0.31	0.95	1.19	0.91	1.67
T	100	24.2	4.42	0.22	0.73	0.28	1.09	1.40	0.87	2.37
NT + S . .	57	24.6	4.23	0.22	0.76	0.26	1.08	1.23	0.91	2.25

NT = pastures without tetany cases.
T = „ with „ „ , just before the samples had been taken.
NT + S = „ without „ „ , supplementary fodder being given.

A comparison of the composition in group NT and that in group T again indicates that herbage taken from pastures with tetany cases has a higher mean potassium and phosphorus content and a lower proportion of sodium, calcium and magnesium. In pastures with tetany cases the ratio of potassium to the other cations is appreciably higher than in pastures without tetany cases. This has already been demonstrated by SJOLLEMA (1931) and VERDEYEN (1952). No great mean differences were found between the crude protein and sulphur contents. The composition of the pasture from group NT + S agrees most nearly with pasture with tetany cases (T), as is also shown by the $\frac{K}{Ca + Mg}$ ratio. This clearly demonstrates the effect of feeding pulp or potato residues (SJOLLEMA, 1931) or magnesium oxide (ALLCROFT, 1947 and SEEKLES, 1955) on the incidence of grass tetany.

This material was treated statistically, an investigation being made into a possible connection between the composition of the pasture and the percentage of grass tetany cases. The grass analyses from the NT + S group were not included in the treatment. A reliable correlation was found to exist for each separate year between the percentage of grass tetany per farm and the potassium and calcium contents of the pasture. This correlation is shown in the following formulas in which T represents the percentage of grass tetany and r the correlation coefficient

1954 : $\log (T + 1) = 4.015\ (\pm 0.705) \log K_2O - 1.971\ (\pm 0.61) \log CaO - 1.950\ (r = 0.752)$.

1955 : $\log (T + 1) = 4.617\ (\pm 0.68) \log K_2O - 4.040\ (\pm 0.52) \log CaO - 5.120\ (r = 0.786)$.

The standard deviation of the regression coefficients are given in parentheses after the coefficients; they show that the coefficients given here are significant.

The symbols for the coefficients indicate that a high potassium content in the pasture favours the occurrence of grass tetany, as does also a lower calcium content. No significant correlation was found with the contents of crude protein, magnesium, phosphorus, chlorine and sulphur, and the effect of the sodium content is not clear. In 1954 the percentage of sodium in the pasture gave a significant negative correlation with the grass tetany percentage, whereas there was no question of any kind of correlation in the more abundant 1955 material. In the entire material the spread of the magnesium contents in the pasture was small compared to that of the other contents. This may explain why in this material it was not found possible during either year to attribute a reliable effect to the magnesium content. Notwithstanding the small spread, the magnesium content in pastures with tetany cases is about 10% lower than in pastures without tetany cases.

Brouwer (1951 and 1952) and Brouwer and Brandsma (1953) believe that the incidence of grass tetany is influenced by the ratio of potassium to calcium and magnesium in the pasture. This ratio is expressed as $\frac{K \times 100}{K + Ca + Mg}$. Verdeyen (1952) employs what is actually the same ratio which he expresses as $\frac{K}{Ca + Mg}$, observing that grass tetany is particularly liable to occur when this ratio in the pasture rises above 2.20. The investigations of Breirem et al. (1949) show that the magnesium content in the ration may also have an effect on the incidence of grass tetany, while the results obtained by Bartlett et al. (1954), which will be discussed below, point in the same direction. From the above it is reasonable to suggest that a possible effect is to be attributed to the magnesium content of the pasture as well as the potassium and calcium contents.

An important problem which needs solution is whether herbage requires an absolutely high potassium content to make it prone to tetany. In Holland grass tetany also occurs in pasture with a potassium content which is normal by Dutch standards, viz. 3.50% potassium oxide in the dry matter. In such cases, however, of which there are not a great number in Holland, the calcium content is very low, as is also very frequently the magnesium content, so that the potassium content is, in fact, relatively high and the calcium and magnesium contents relatively very low. In all cases we find a high ratio of potassium to calcium + magnesium.

British research workers have pointed out that in Scotland, for example, grass tetany frequently occurs in pastures with normal potassium contents which must be reckoned as low by Dutch standards. However, it is not impossible that in this case the pasture still has a high $\frac{K}{Ca + Mg}$ ratio, although there is no data to confirm this. Elliott et al. (1926) give the mean potassium and calcium contents of grass derived from Scottish hill pastures. The potassium contents of this grass are admittedly low, but the calcium contents were very low. The average $\frac{K}{Ca}$ ratio in this grass is higher than that now found on Dutch farms not affected by tetany. The Scottish pastures had high sodium contents, but the magnesium contents were not determined.

In the States of Oklahoma and Texas a form of tetany occurs in cattle that greatly resembles the grass tetany occurring in Holland. It is found in cattle grazing on young wheat pastures during winter and the early spring (wheat poisoning). DEIJS et al. (1954) reported the composition of a number of wheat samples from Oklahoma on which the disease had been identified. Their $\frac{K}{Ca + Mg}$ ratio was found to be very high, viz. 2.69.

Fig. 3 shows that there is a sharp rise in the tetany percentage in Holland as the $\frac{K}{Ca + Mg}$ ratio in the pasture increases.

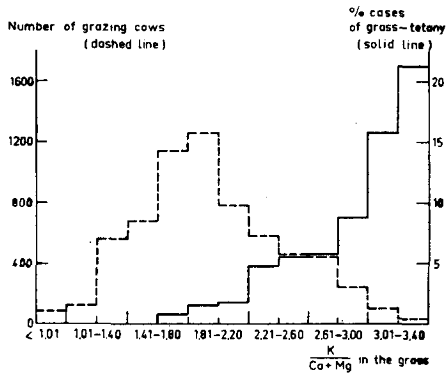

FIG. 3 RELATIONSHIP BETWEEN THE $\frac{K}{Ca + Mg}$ RATIO IN THE PASTURE GRAZED BY THE ANIMALS AND THE NUMBER OF TETANY CASES, EXPRESSED AS THE PERCENTAGE OF THE NUMBER OF ANIMALS IN EACH GROUP.

In 1954 and 1955 determinations were made of the composition of pasture ingested by 6566 grazing dairy cows. The animals were not given any supplementary feed of pulp, potato residues or magnesium oxide. Of these 6566 milking cows 163, or 2.48 %, were suffering from grass tetany. Fig. 3 shows that the highest percentage of tetany occurs when the $\frac{K}{Ca + Mg}$ ratio in the pasture is at its maximum. 4658 milking cows grazed in pasture having a $\frac{K}{Ca + Mg}$ ratio lower than 2.21 and 0.77 % of these animals were affected by tetany. 1908 animals grazed on pasture having a ratio higher than 2.20, and of this number 6.66 % were suffering from tetany. The tetany percentage increases in particular above the 2.20 limit referred to by VERDEYEN (1952). An important deduction from Fig. 3 is that the animals are particularly prone to tetany when the composition of the herbage differs from the one they normally graze on.

For practical purposes it is very important to discover what factors influence the $\frac{K}{Ca + Mg}$ ratio in the pasture. The potassic and nitrogenous fertilization and the botanical composition of the sward may be mentioned as important in this connection.

Clovers and weeds usually have a lower ratio than grasses, so that the greater the proportion of clover and weed in the total ration the lower is the ratio. VAN DER KLEY's investigation (1956) suggests that the greater the $\frac{K}{Ca + Mg}$ ratio in the pasture the smaller is this effect. 'T HART and KEMP find (1956) that the maximum number of tetany cases occur when a heavy dressing of a nitrogenous fertilizer is applied to the sward in addition to an excessively heavy dressing of a potassic fertilizer. (See Table 3).

Table 3 Effect of nitrogenous and potassic fertilization on the incidence of grass tetany.

Potash supply	Inadequate		Adequate		Excessive		Total	
	n	T %	n	T %	n	T %	n	T %
0–51 kgs N per hectare	662	0.60	889	1.24	823	3.65	2374	1.90
> 50 kgs N per hectare	102	0	442	0.23	1024	6.45	1568	4.27
Total	764		1331		1847		3942	
Average		0.52		0.90		5.20		2.84

n = number of milking cows T % = Tetany %.

This table shows the percentage of grass tetany cases occurring with the heavy and light use of nitrogenous fertilizers, and when the soil has an inadequate, adequate and too rich supply of potash. An inadequate supply of potash means that by comparison with established norms the potash content of the soil and the potassic fertilizer applied by the farmer provides too little potash to ensure the maximum yield of herbage. An investigation was carried out in the same way to determine which fields had an adequate or excessive supply of potash. Unlike the fields which had an excessive supply of potash, in those which had an adequate or inadequate amount the highest percentage of grass tetany was found in animals grazing o fields with the lightest nitrogen dressings.

Experiments on the effect produced on the mineral composition of pasture by different amounts of nitrogen and potash showed that the $\frac{K}{Ca + Mg}$ ratio increased considerably as the potassic fertilization increased. The highest ratios were found when a heavy dressing of a nitrogenous fertilizer was given in addition to an excessively heavy dressing of a potassic fertilizer. This applies to spring grass harvested at a very early stage. But increasing applications of nitrogen produce a lower $\frac{K}{Ca + Mg}$ ratio according as there is less potassium in the soil and the grass is harvested at a later stage of growth in a greater yield. This would explain the different effects of nitrogenous fertilization on the percentage of grass tetany cases, and might also explain why many workers are of the opinion that pasture is less prone to tetany the more advanced its stage of growth and the greater the yield.

BARTLETT et al. point out (1954) that a heavy use of nitrogenous fertilizers is particularly dangerous from the point of view of grass tetany. His experiments were designed to study the effect of nitrogen and potash dressings on the blood magnesium level of milking cows, and the incidence of grass tetany. Note was also taken of the effect of applying magnesium to the sward. The nitrogen dressing, in this case applied in the form of sulphate of ammonia, resulted in a pronounced fall in the serum magnesium level. When a very heavy magnesium dressing was applied in addition to a nitrogen one the fall was found to be much slighter. In this two-year experiment no fall in serum magnesium level was observed during the first year on the plot which had received a potash dressing. On this plot there was a very high proportion of clover. During the second year there was a marked fall in serum magnesium after the clover had been suppressed with a hormonal spray, and this fall was greater than in the unfertilized plot. No nitrogenous fertilizers were used on the plot dressed with potash. Despite the fact that in these experiments there are insufficient analyses of the sward, so that the findings cannot be compared at all points with our own results, there is strong evidence to show that the results obtained by BARTLETT et al. agree with those outlined here, since in the first place it is very probable that the $\frac{K}{Ca + Mg}$ ratio in the grass of the nitrogen + magnesium plot was lower than in the grass of the nitrogen plot on account of the magnesium content being nearly twice as high. In this case a considerably slighter fall in magnesium content would be accompanied by a lower $\frac{K}{Ca + Mg}$ ratio in the grass, and this agrees with our own observations. The fact that the serum magnesium levels fell in the plot dressed with potash after the clover had been suppressed points in the same direction. In this case also a lower $\frac{K}{Ca + Mg}$ ratio in the total ration is to be anticipated as a result of the substantially higher calcium and magnesium contents of clover compared to grass. In the experiments conducted by BARTLETT et al. it is very likely that there would have been a far greater fall in the serum magnesium levels had a nitrogenous fertilizer been used in addition to the potash dressing.

An experiment performed by the Central Institute of Agricultural Research demonstrates very clearly that the application of a potassic fertilizer to grassland has a striking effect on the serum magnesium levels in dairy cows. 16 milking cows were used for the experiment, 8 grazing on plots with a normal potash dressing and 8 on pasture with a heavy potash dressing. The greatest differences between the mean serum magnesium values in the two groups of dairy cows were recorded in the spring and autumn and were occasionally as much as 1.0 mg of magnesium per 100 cc of serum. The plots with heavy and normal potash dressings both received the same amount of nitrogen dressing.

3 THE EFFECT OF TEMPERATURE ON THE COMPOSITION OF THE PASTURE IN CONNECTION WITH THE INCIDENCE OF GRASS TETANY

In the first chapter we showed that both the temperature level and the fluctuations below a level of 14° C exerted an effect on the frequency curve of tetany. It was queried whether this correlation might not be partly explained by a change in the composition of the pasture as a result of the temperature.

In the second chapter we described how the $\frac{K}{Ca + Mg}$ ratio in the pasture is significant correlated to the incidence of grass tetany. Finally, an investigation was made into the effect of temperature on the composition of the pasture, and the findings were correlated to the incidence of grass tetany.

The effect of temperature was investigated, *inter alia,* on an experimental field on sandy grassland laid out in the spring of 1955. A soil thermograph supplied by the Royal Netherlands Meteorological Institute, De Bilt, was placed on the field and the soil temperatures measured with it at a depth of 3 cm. The experimental field was fertilized with 120 kg of K_2O and 60 kg of N per hectare. A grass sample in which the crude protein, potassium, sodium, calcium and magnesium contents were determined was taken every two or three days.

The mean 24-hour soil temperature recorded, and the composition of the pasture for the various data, are shown in Fig. 4.

From 24th to 30th April the soil temperature shows a steep rise from 7 to

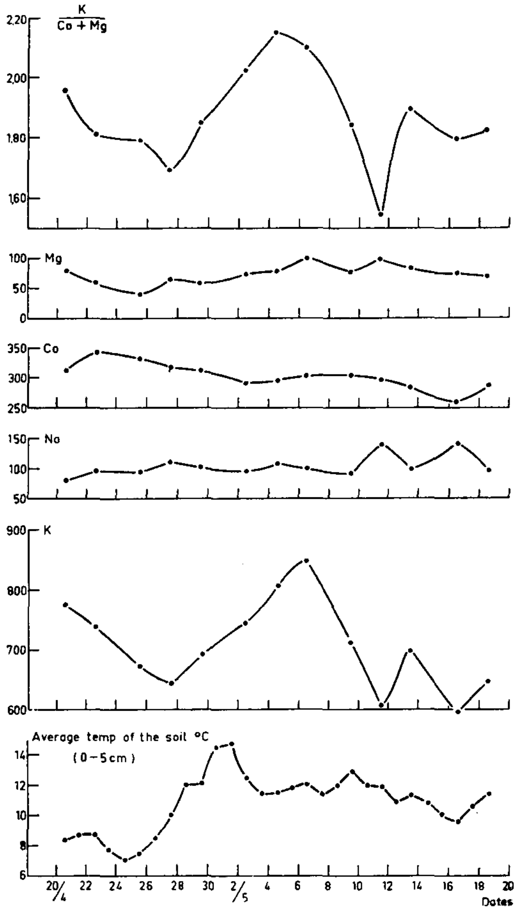

FIG. 4 RELATIONSHIP BETWEEN FLUCTUATIONS IN THE TEMPERATURE OF THE SOIL AND THE COMPOSITION OF THE PASTURE IN MILLIEQUIVALENTS PER KG OF DRY MATTER (1955).

15° C. This is succeeded by a fall to 11 to 12° C, after which the temperature continues to fluctuate around this level for a considerable time. A comparison of these variations in temperature with the contents in the pasture shows that the potash content alone is substantially affected. From 27th April to 6th May this increases to 200 milliequivalents, or nearly 1% of K_2O in the dry matter. Subsequently there is a fall in the potassium content until 11th May, after which there are only slight fluctuations which it is also possible to associate with preceding fluctuations in the temperature.

As also appears from the results obtained by DIJKSHOORN and 'T HART (1957), published elsewhere in this number, a rise in temperature results in an increase in the potassium content, while a fall in temperature leads to a decline in the potassium content. In 1949 'T HART also found a rise in the potassium content with rising temperatures. The fall in the potash content beginning on 6th May is of longer duration than the preceding fall in temperature. This is probably due to the fact that from 3rd to 7th May the soil temperature continued to fluctuate around practically the same level, whereas owing to the constantly increasing production of dry matter the potassium content took longer to fall. The crude protein contents (not shown in the figure) decrease regularly as the plant grows older. As in this experiment the calcium and magnesium contents reacted only slightly to a change in temperature it is understandable that the $\frac{K}{Ca + Mg}$ ratio also changes as a result of the highly sensitive potassium content (see Fig. 4). This ratio reaches its maximum on 5th May. In practice most tetany cases occurred about this date (see Fig. 5). Hence an increasing number of tetany cases after a rising temperature is attended by an increase in the $\frac{K}{Ca + Mg}$ ratio in the pasture. Vice versa, a decline in the number of tetany cases after a falling temperature is attended by a lower $\frac{K}{Ca + Mg}$ ratio.

We can see that the same temperature effect occurs in Fig. 5 which was compiled from data from another source. This figure gives the composition, for the various data, of the pasture in a large number of different plots with and without tetany cases.

These samples from plots with a normal to very high potash content in the soil were taken in April and May 1955, during which period the tetany cases shown in Fig. 5 also occurred.

As in Fig. 4, no reliable change in the calcium and magnesium contents can be observed in this case either, although there is a marked peak in the potassium content on 5th or 6th May approximately coinciding with the peak in the tetany frequency. After making a calculation it was found that both the rise and fall in the potassium content caused by the preceding rise and fall in temperature were significant factors. In this figure the $\frac{K}{Ca + Mg}$ ratio after a rise in temperature is also higher than after a fall in temperature. The fact that in both figures (4 and 5) the date on which the highest $\frac{K}{Ca + Mg}$ ratio is found in the pasture approximately coincides with the date on which

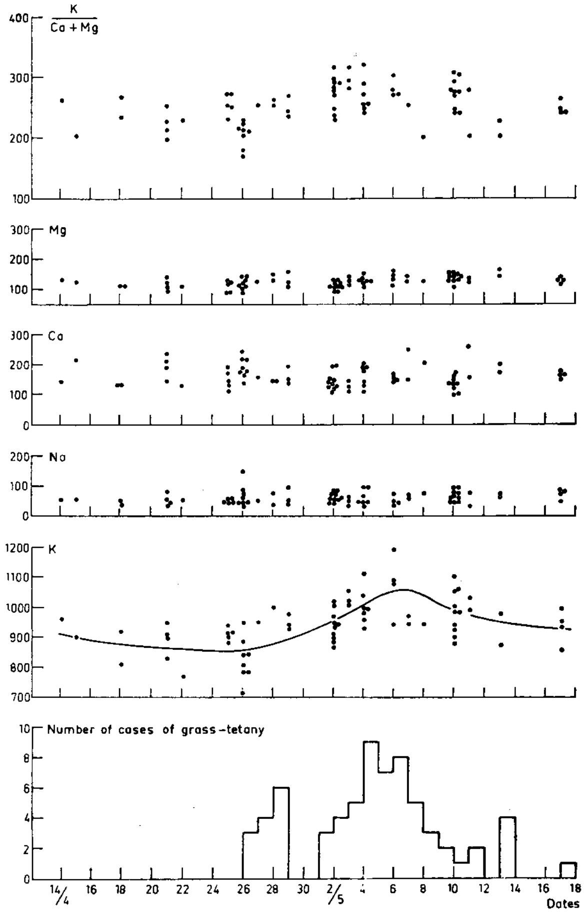

FIG. 5 COMPOSITION, FOR VARIOUS DATA, OF GRASS TAKEN FROM A NUMBER OF DIFFERENT FIELDS, IN MILLIEQUIVALENTS PER KG OF DRY MATTER (1955).

the greatest number of tetany cases actually occurred is a confirmation of the correlation of the $\frac{K}{Ca + Mg}$ ratio in the pasture to the incidence of tetany.

Our observations also lead us to the conclusion that more time is required for a change in the composition of the pasture caused by a change in temperature than the time elapsing between the grazing of pasture and the possible occurrence of symptoms.

In the foregoing we did not discuss the influence of consistently low and high temperatures on the composition of the pasture. We have seen that very few cases of tetany occur in summer when the temperatures are higher than in spring or autumn. The $\frac{K}{Ca + Mg}$ ratio must therefore be lower in summer pastures than in spring and autumn pastures. This is, in fact, borne out by BRANDSMA's data (1954), the ratios being 1.51, 1.25 and 1.45 in April and May, July and August and September respectively. DEIJS and BOSCH reported (1951) that the calcium and magnesium contents in the pastures were higher during the summer than in the spring or autumn. This is also the case in BRANDSMA's material. DIJKSHOORN and 'T HART (1957) found from pot tests that the $\frac{K}{Ca + Mg}$ ratio in grass grown at mean 24-hour temperatures of 20° C was lower than in grass grown at 10° C. It follows from this data that the virtual non-existence of tetany during the summer coincides with a lower $\frac{K}{Ca + Mg}$ ratio in the pasture. The higher proportion of clover in the herbage during summer, compared to that during spring and autumn, may also have a substantial effect on this ratio. Clover having a far higher level of calcium this leads to a lower $\frac{K}{Ca + Mg}$ ratio.

It should be mentioned in conclusion that this data, like the results of the experiments conducted by DIJKSHOORN and 'T HART (1957) make it probable that the statistically proven relationship between temperature and the incidence of grass tetany is correlated to the cationic composition of the herbage ingested by the animal.

ACKNOWLEDGMENTS

The authors' thanks are due to Professor J. A. BEIJERS of the Faculty of Veterinary Medicine of the University of Utrecht for supplying the statistical data, making the diagnoses and giving directions. They are also indebted to Ir. J. WIND, Director of the Central Institute for Agricultural Research at Wageningen and to Dr. W. B. DEYS, Principal of the Chemistry Department of this Institute, for the help afforded, and to Messrs. C. POSTMA and C. DE JONGE for their mathematical treatment of the results of the investigation. Moreover they wish to thank the working party "Grass tetany research" for suggesting the line of work.

REFERENCES

ALLCROFT, W. M.: *Veterinary Journal* 103 (1947) 75–100.

– – and H. H. GREEN: *Journal of Comparative Pathology* 51 (1938) 176–191.

BARTLETT, S., B. B. BROWN, A. S. FOOT, S. J. ROWLAND, RUTH ALLCROFT and W. H. PARR: *British Veterinary Journal* 110 (1954) 3–19.

BRANDSMA, S.: *Mededelingen van de Landbouwhogeschool te Wageningen* 54 (1954) 245–309.

BREIREM, K., F. ENDER, K. HALSE and L. SLAGSVOLD: *Acta Agriculturae Suecana*, Vol. III (1949) 89–120.

BROUWER, E.: *British Veterinary Journal* 108 (1952) 123.

– –: *Mededelingen van de Landbouwhogeschool te Wageningen* 51, nr. 4 (1951) 91–112.

– – and S. BRANDSMA: *Mededelingen van de Landbouwhogeschool te Wageningen* 53, nr. 3 (1953) 31–73.

DEIJS, W. B. and S. BOSCH: *Maandblad Landbouwvoorlichting*, nr. 8 (1951) 381.

– –, J. v. D. GRIFT, L. SEEKLES and J. WIND: Rapport Studiegroep Landbouw (1954).

DIJKSHOORN, W. and M. L. 'T HART: *Netherlands Journal of Agricultural Science*, Vol. 5, nr. 1 (1957) 24–42.

ELLIOTT, W. E. et al.: *Journal of Agricultural Science* 16 (1926) 59–104.

HART, M. L. 'T: *Plant and Soil* I (1949) 263–270.

– – and A. KEMP: *Tijdschrift voor Diergeneeskunde* 81 (1956a) 84–95.

– –, – –: *Landbouwvoorlichting*, nr. 3 (1956b).

INGLIS, J. S. S., MARY WEIPERS and A. MARR: *Veterinary Record*, Vol. 66, nr. 25 (1954).

KLEY, F. K. v. D.: *Netherlands Journal of Agricultural Science*, Vol. 4, nr. 4 (1956) 314–332.

SEEKLES, L.: *Tijdschrift voor Diergeneeskunde*, nr. 8 (1955) 331–346.

SJOLLEMA, B.: *Landbouwkundig Tijdschrift* 43 (1931) 67–77; 139–147; 593–610; 793–815.

– –: *Landbouwkundig Tijdschrift* 63 (1951) 569–640.

VERDEYEN, J.: *Compt de Rend. de Rech. de 'l I.R.S.I.A.*, nr. 9 (1952).