The influence of management and nitrogen application on the botanical composition of grassland

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Summary

Management and nitrogen application had a great effect on the botanical composition, which appeared to adapt itself to the treatments in one or two seasons, after which no further systematic changes occurred. Annual fluctuations occurred as a result of weather conditions. The contrast in botanical composition was greatest with grazing *vs.* cutting. Next in importance were soil moisture and frequency of cutting (3-weeks *vs.* 5-weeks). N-application (70 kg N/ha) was less important than the system of grazing (rotational *vs.* continuous grazing) or the frequency of cutting.

The frequency percentages followed the same trend as the dry-weight percentages, but their differences were relatively smaller.

The number of moles was much larger in continuously grazed plots than in rotationally grazed ones. There were also more moles in the rotationally grazed plots with low N-application than in those with high N-application.

1. Introduction

The influence of continuous grazing and rotational grazing on the botanical composition of the sward was studied from 1954 to 1961 on a permanent pasture on sandy soil at Wageningen. The results of the first three years have been published in an earlier paper (ENNIK, 1957). As each treatment had only two replicates, the treatments were changed to the different plots at the beginning of 1958. In 1955 some cutting treatments were added to the experiment. The results of the whole experiment are discussed in the present paper.

2. Method

The experimental lay-out is shown in FIG. 1. The experiment was carried out on a permanent pasture divided lengthwise into two parts which were alternately grazed or cut for hay with pre- and post-grazing annually. The experiment was started in the spring of 1954 and comprised the following four treatments in duplicate (plot size 23 are): –

I. Continuous grazing with no post-grazing treatment. Grazed by two yearlings per plot from May to October, with a rest period of 5—6 weeks in July—August. Total N-application about 70 kg N per ha per year given in the form of ammonium nitrate limestone in two dressings (spring and summer).

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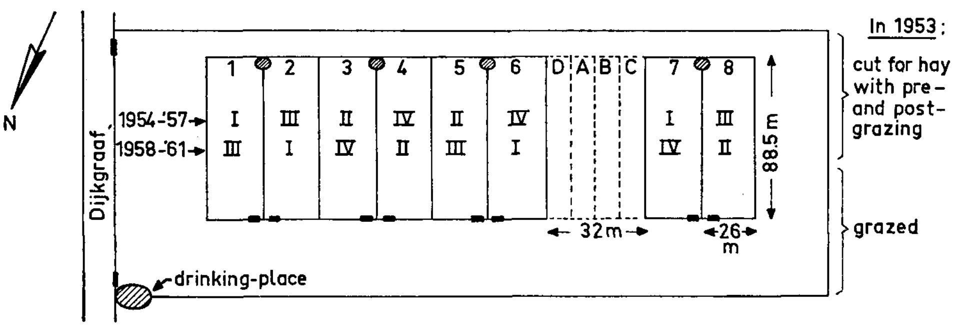
II. As No. I but with topping of the ungrazed spots and spreading of the dung after each grazing period (in summer and autumn).
III. Rotational grazing. In combination with the plots of No. IV alternately grazed by eight to ten yearlings and pregnant heifers about 5—6 times a year, the length of one grazing period varying from 3—8 days. After each grazing the plots were topped and the dung collected to prevent the grass from smelling, except for the first year when it was spread after each grazing, and stored outside the plot for redistribution in winter. Total N-application about 70 kg N per ha per year, which was distributed over the season according to the grazing periods.
IV. As No. III but with double N-application (about 140 kg N per ha per year).

From 1954 to 1957 these treatments were maintained on the same plots. In 1958 they were changed in such a way that continuously grazed plots were rotationally grazed and *vice versa* (FIG. 1). The area outside the experimental plots was used as

FIG. 1. Lay-out of the experiment. I to IV: grazing treatments; A to D: cutting treatments



Grazing treatments
I. Continuous grazing. No post-grazing treatment, low N-application (approx. 70 kg/ha).
II. - do - Post-grazing treatment, low N-application (approx. 70 kg/ha).
III. Rotational grazing. Low N-application (approx. 70 kg/ha).
IV. - do - High - do - (approx. 140 kg/ha).

Cutting treatments
A. 3-week cutting, low N-application (approx. 70 kg/ha).
B. - do - high - do - (approx. 140 kg/ha).
C. 5-week cutting, low - do - (approx. 70 kg/ha).
D. - do - high - do - (approx. 140 kg/ha).

a reserve for periods with insufficient grass growth on the experimental plots. Generally a part of this area was cut for hay. In 1954 the strip between plots 6 and 7 was also used for this purpose. After grazing in spring it was cut for hay and one part (the later strips D and A) cut twice in a young stage of growth and another part (the later strips B and C) four times. In 1955 this area between plots 6 and 7 was included in the experiment, comprising the following cutting treatments (FIG. 1): –

A. Cut every 3 weeks with low N-application (about 70 kg N per ha per year). As in the other cases the nitrogen was distributed over the season according to the cuttings. On an average 8 cuts a year.
B. Cut every 3 weeks with high N-application (about 140 kg N per ha per year). On an average 8 cuts a year.

C. Cut every 5 weeks with low N-application (about 70 kg N per ha per year). On an average 5 cuts a year.
D. Cut every 5 weeks with high N-application (about 140 kg N per ha per year). On an average 5 cuts a year.

These treatments were maintained on the same plots throughout the experiment. The plots were cut by an autoscythe to a height of about 4 cm. After cutting the grass was removed immediately or after a few days' drying.
The dry-weight percentages of the species in the sward were twice determined in 1954 by the method described by DE VRIES (1940a, 1959) and afterwards three times a year. The frequency of occurrence of the different species was also determined in the autumn of 1956 and in the spring of 1958—1961 (DE VRIES, 1940b, 1959).

2.1 Soil

The degree of humidity of the soil increased from plot 1 to plot 6. The rear part of the field (plots 6 to 8 and A to D inclusive) was rather wet during rainy periods, and in most years suffered from excess of water in autumn and winter. Consequently the grass growth was rather late in spring. An analysis of the soil to a depth of 5 cm in December 1954 showed that the soil fraction below 16 μ was lowest in the front part of the field (11 %) and highest in the rear part (17 %). The pH-KCl varied irregularly from 5.2 to 5.8 and the organic-matter content from 7.6 to 10.7 (lowest on the cutting strip between plots 6 and 7, and highest on plots 5 and 6).
The P-status and K-status of the soil were rather high to high. The MgO-content varied from 0.011—0.015 %. To maintain an adequate nutrient status of the soil the grazed plots received an annual dressing of approximately 10 kg P_2O_5 and 55 kg K_2O per ha. In the first two years a Mg dressing was given of 30 kg MgO and 10 kg MgO per ha. The cutting plots were dressed with approximately 60 kg P_2O_5, 240 kg K_2O and 30 kg MgO per ha per year, including a compensation for the removal of these elements by continuous cutting. No compensation was given to these plots for the loss of N in comparison to the grazed plots.
A topography and survey of soil-water levels and evaluation of the sward of a zone of grasslands including the experimental field is given by DE BOER (1950). Plot No. 63 on his map No. 1 corresponds to our experimental field. According to BURINGH (1951) the soil of the experimental field may be described as an intermittently wet, slightly loamy grassland cover-sand soil.

2.2 Weather

In 1954 a dry spring was followed by an extremely wet summer and autumn, resulting in an excess of water and trampling of the sod. The dry and sunny summer of 1955 was favourable for grass growth on the experimental field. The summer of 1956 was very wet again with excess of water continuing until winter. Both 1957 and 1958 were average seasons with spells of excessive water in the autumn. The summer and autumn of 1959 were extremely dry and grass growth was seriously limited as a result. As a consequence of the low water level in winter grass growth in spring 1960 was early and abundant. A normal summer was followed by a very wet autumn with excessive water again.

3. Results

The dry-weight percentages of the main species at different times are represented in FIG. 2 for the grazing treatments and in FIG. 3 for the cutting treatments. The lines in FIG. 2 are means of the two plots per treatment.

As FIG. 2 shows, the difference in grazing treatment caused great differences in botanical composition, especially for *Lolium perenne* and *Holcus lanatus* (the percentages will be examined in more detail later in this article). It is noticeable that most of the differences were already found in the first season. To obtain some information on the actual effect of the grazing technique and a possible disturbing effect of heterogeneity of the field, the treatments were changed to the different plots in the beginning of 1958, as indicated in FIG. 1. Continuously grazed plots were rotationally grazed and *vice versa.* The graphs of *Lolium perenne* and *Holcus lanatus* show that the botanical composition adapted itself to the new treatments in almost one season. No important systematic changes occurred in the following years.

It is evident, however, that the percentages of some species after the change do not always correspond with those on the same treatment before the change (*e.g. Lolium perenne* with continuous grazing and *Holcus lanatus* with rotational grazing). It is not known whether this is characteristic of changing treatments (possibly revealing a process of very slow adaptation) or due to accidental factors or heterogeneity of the field.

The conclusion that the botanical composition (expressed in dry-weight percentages) soon adapts itself to the treatment is confirmed by FIG. 3 for the cutting treatments, the main differences between the treatments already being found in the first season. At first there is a steady increase of *Holcus lanatus* on the cutting treatments as a whole, but in this case also the optimal value is reached within two years (spring 1957). The cutting treatments were not changed during the experiment and are therefore more suitable for providing information on changes in botanical composition over a longer period. They do not indicate slow adaptation. Although there are no replicates for the cutting treatments, some idea may be gained of the reliability of the differences in weight percentages between the treatments by comparing these differences with the original proportions in the spring of 1955. The mutual fluctuations of the lines in the course of time give some information on the constancy of the differences, the collective fluctuations from year to year being due to climatic conditions.

The dry-weight percentages of the different species for each treatment are summarized in TABLE 1. From the conclusions reached in FIG. 2 and 3 it is assumed that the botanical composition is adapted to treatment in the autumn of the year in which the treatment was started. As the spring analyses were made before grazing was started, the analyses of the grazing plots in spring 1958 are included in the preceding treatment. In the same way the frequency percentages are summarized in TABLE 2. It can be seen that they generally follow the same trend as the weight percentages, but the differences between the frequency percentages are relatively smaller.

Of the seven main species (each contributing more than 3 % to the sward, averaged over the grazing treatments) the order of preference for the different treatments or conditions was determined by calculating the relative preferences

$$^{\mathrm{nm}}\pi_{\mathrm{a}} = {}^{\mathrm{n}}P_{\mathrm{a}} / {}^{\mathrm{m}}P_{\mathrm{a}}\,,$$

in which P is the mean dry-weight percentage of species a undergoing a certain treatment (TABLE 1), n and m the treatments being compared, and π the relative preference of species a for treatment n rather than treatment m. π greater than 1 means that treatment n is preferred to treatment m under the prevailing conditions; when π is smaller than 1 the converse is true. Whether or not a species is favoured by

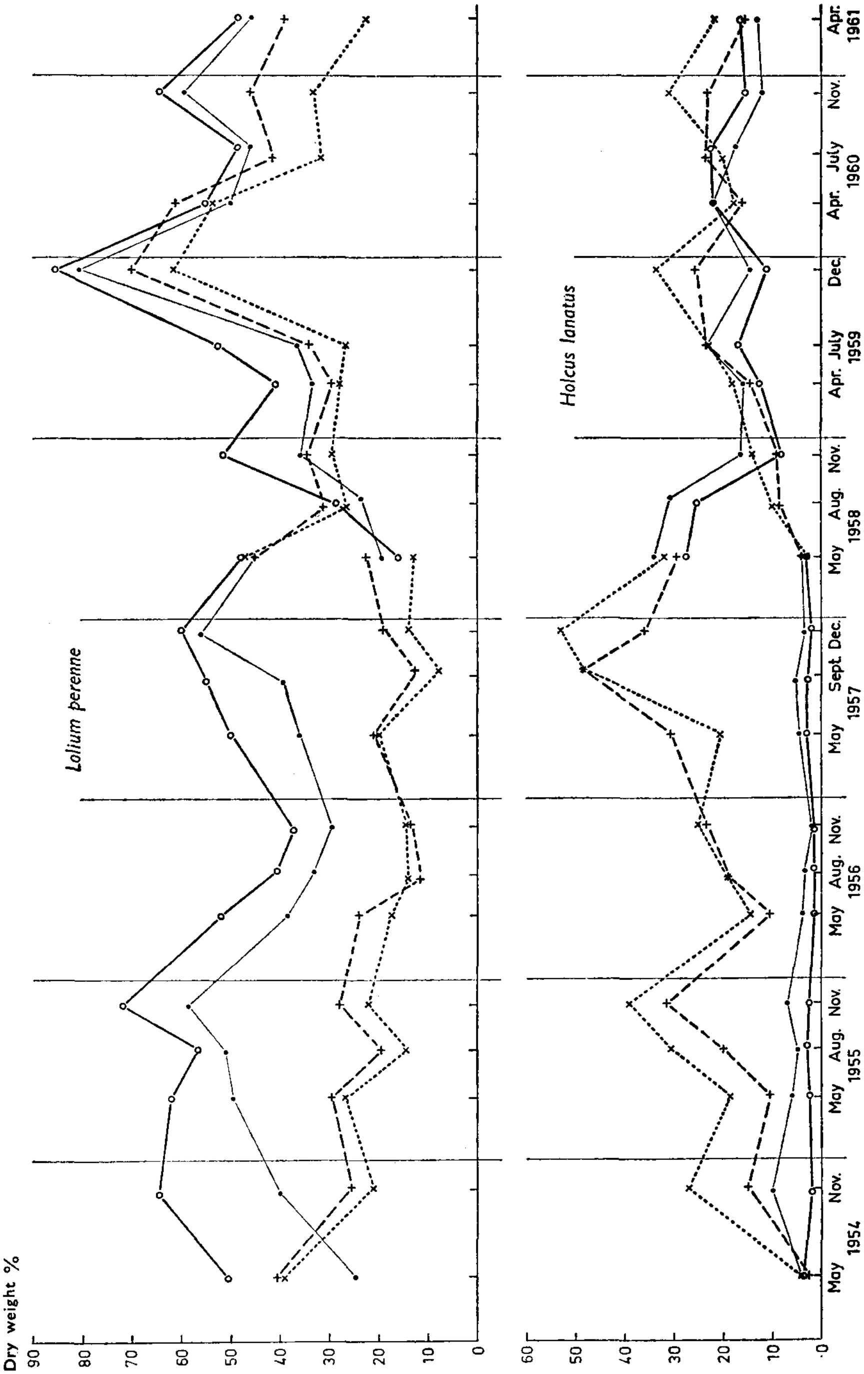
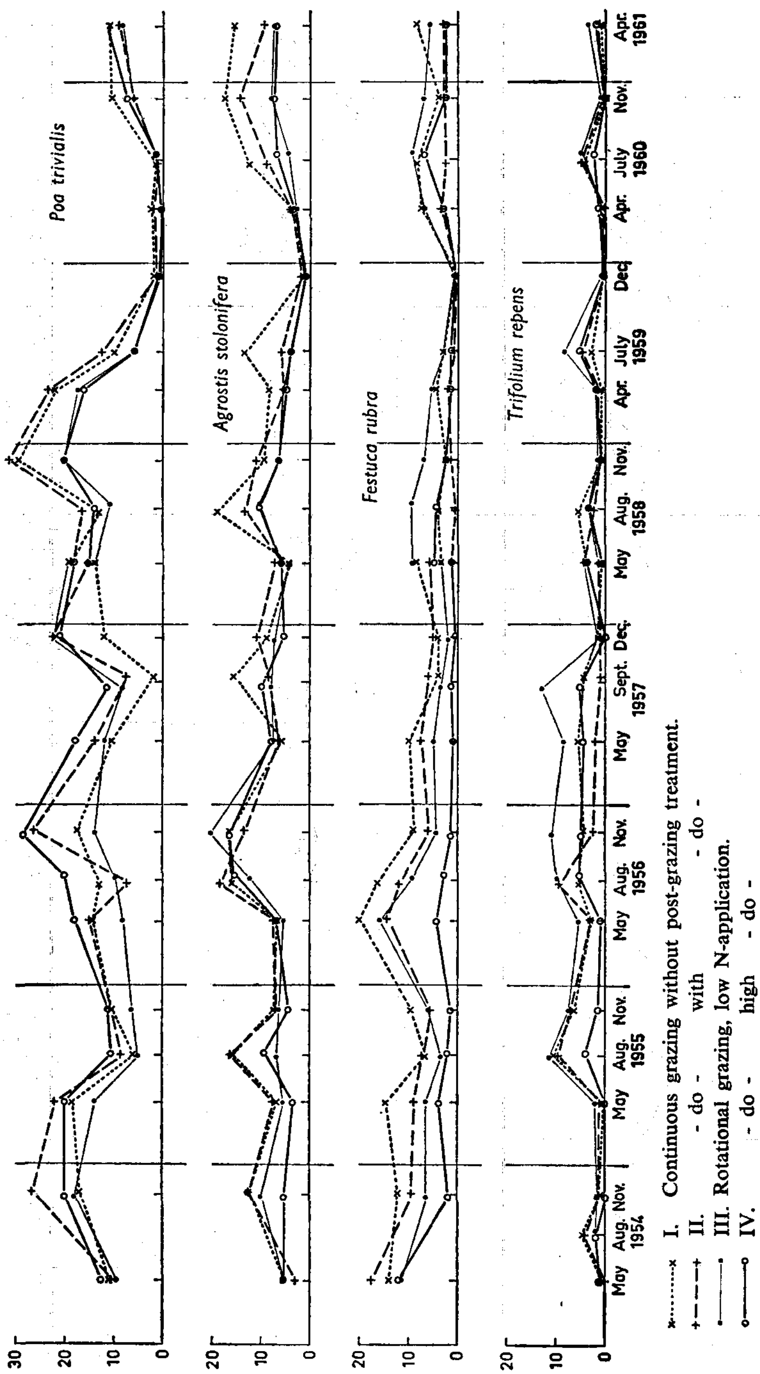


FIG. 2. Grazing treatments. Dry-weight percentages of the most important species during the experiment (means of two plots per treatment). Change of treatments in spring 1958.


Poa trivialis
Agrostis stolonifera
Festuca rubra
Trifolium repens
May Aug. Nov. 1954
May Aug. Nov. 1955
May Aug. Nov. 1956
May Sept. Dec. 1957
May Aug. Nov. 1958
Apr. July Dec. 1959
Apr. July Nov. 1960
Apr. 1961
I. Continuous grazing without post-grazing treatment.
II. - do - with - do -
III. Rotational grazing, low N-application.
IV. - do - high - do -

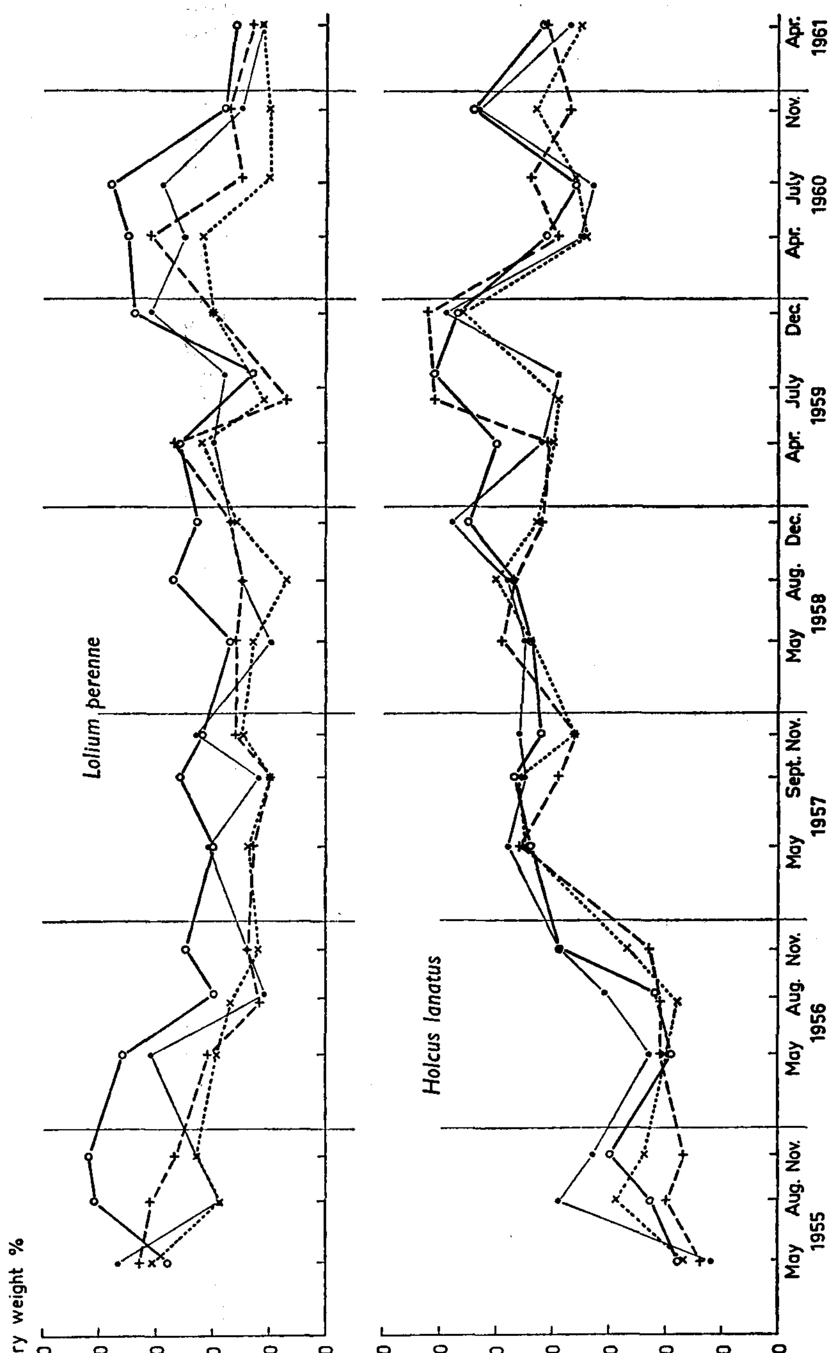


FIG. 3. Cutting treatments. Dry-weight percentages of the most important species during the experiment.

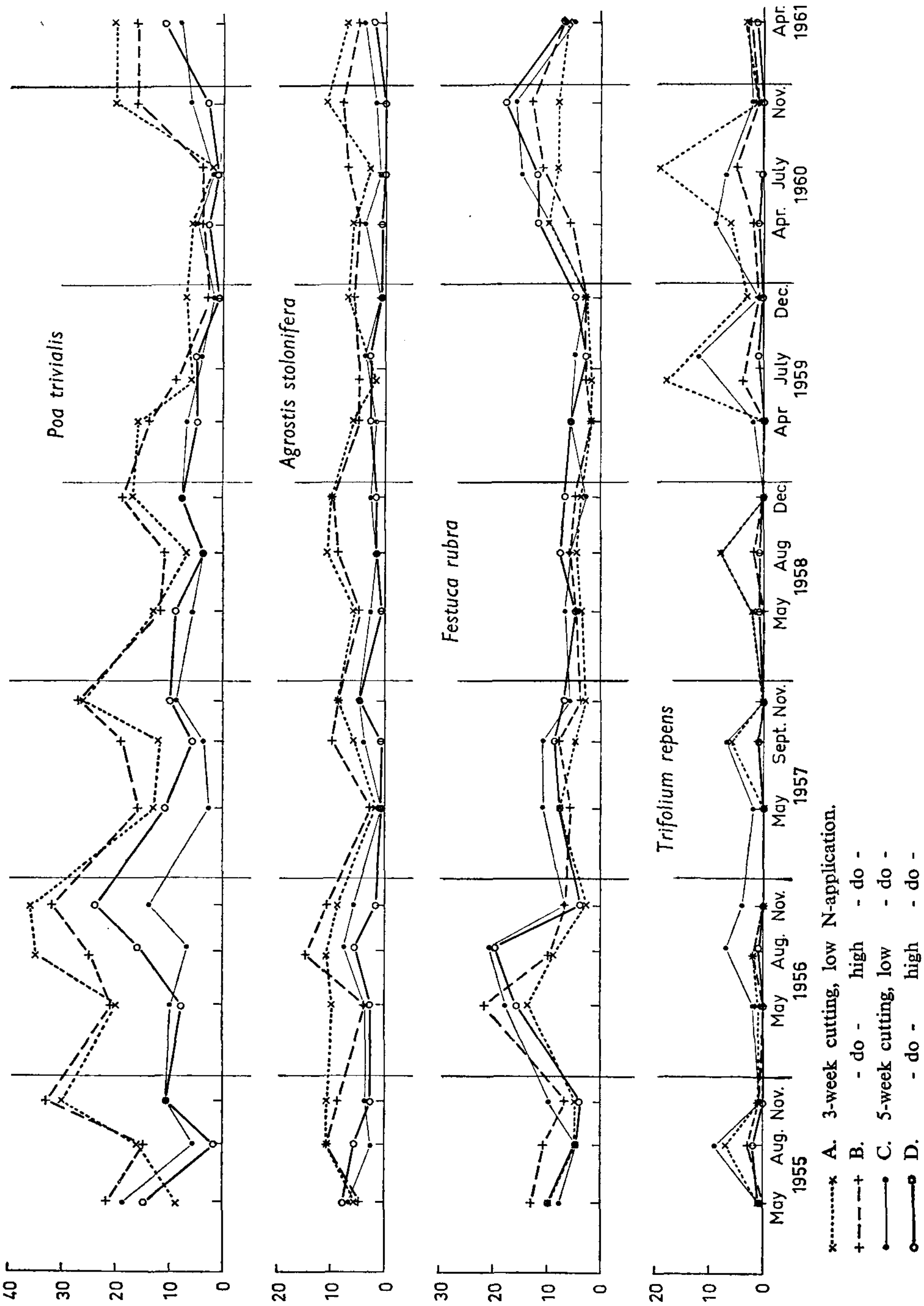

Poa trivialis
Agrostis stolonifera
Festuca rubra
Trifolium repens
May 1955
Aug.
Nov.
May 1956
Aug.
Nov.
May 1957
Sept.
Nov.
May 1958
Aug
Dec
Apr 1959
July
Dec.
Apr. 1960
July
Nov.
Apr. 1961
A. 3-week cutting, low N-application.
B. - do - high - do -
C. 5-week cutting, low - do -
D. - do - high - do -

TABLE 1. Dry-weight percentages of the main species per treatment. Data of the grazed plots (treatment I–IV – bold print) are averages of all analyses (19 of each of the two plots per treatment) during the periods autumn 1954 to spring 1958 and autumn 1958 to spring 1961. The data of the separate plots are shown in ordinary print in the same columns; the left-hand figures refer to plots 1 to 4, the right-hand figures to plots 5 to 8 in FIG. 1. Data of the cut plots (treatments A—D) are averages of all (17) analyses during the period autumn 1955 to spring 1961.

Species	Grazing treatment												Cutting treatment			
	I			II			III			IV			A	B	C	D
Lolium perenne L.	22.8	**24.8**	26.7	32.2	**30.6**	29.1	46.5	**45.4**	44.4	58.9	**55.0**	51.0	14.8	17.1	19.2	25.8
Holcus lanatus L.	29.3	**26.6**	23.9	20.6	**22.4**	24.2	8.6	**10.0**	11.4	6.8	**7.9**	9.1	37.4	39.2	42.0	42.9
Poa trivialis L.	9.0	**11.8**	14.6	12.7	**13.8**	14.9	9.1	**10.4**	11.8	11.2	**13.8**	16.3	16.8	16.5	6.5	8.0
Agrostis stolonifera L.	8.8	**10.5**	12.3	8.8	**9.4**	9.9	5.2	**7.1**	9.1	4.8	**7.0**	9.2	7.5	7.4	3.4	2.1
Festuca rubra L.	14.2	**8.1**	2.0	9.5	**5.5**	1.6	10.2	**5.9**	1.7	3.9	**2.3**	0.7	5.8	7.4	9.4	8.9
Anthoxanthum odoratum L.	1.8	**1.8**	1.8	1.3	**1.5**	1.6	1.5	**1.3**	1.1	0.6	**0.6**	0.5	3.0	2.6	3.6	2.1
Festuca pratensis HUDS.	0.7	**0.7**	0.7	0.6	**1.0**	1.4	1.1	**1.1**	1.2	0.8	**1.0**	1.2	0.5	0.2	0.7	0.9
Cynosurus cristatus L.	1.3	**0.9**	0.5	0.8	**0.9**	0.9	1.8	**1.3**	0.8	1.3	**1.0**	0.7	1.4	1.1	1.6	1.2
Agrostis tenuis SIBTH.	1.6	**1.6**	1.6	1.2	**1.1**	1.1	0.7	**0.6**	0.5	0.6	**0.4**	0.2	2.9	1.7	0.5	0.2
Alopecurus geniculatus L.	0.1	**0.5**	0.9	0.4	**0.7**	1.1	0.1	**0.8**	1.5	0.6	**1.0**	1.4	0.1	0.2	0.1	0.4
Poa pratensis L.	0.8	**0.6**	0.3	0.6	**0.6**	0.5	0.7	**0.7**	0.6	0.6	**0.4**	0.3	0.4	0.8	0.9	1.4
Phleum pratense L.	0.1	**0.3**	0.6	0.1	**0.6**	1.1	0.4	**0.6**	0.8	0.1	**0.3**	0.6	0.5	0.9	0.6	0.4
Alopecurus pratensis L.	0.2	**0.2**	0.2	0.3	**0.3**	0.3	0.1	**0.4**	0.7	0.1	**0.1**	0.1	0.5	0.1	0.3	0.4
Poa annua L.	0.1	**0.2**	0.4	0.2	**0.2**	0.2	0.1	**0.2**	0.2	0.4	**0.3**	0.2			0.0	
Glyceria fluitans R. BR.	0.1	**0.2**	0.3	0.1	**0.1**	0.1	0.3	**0.2**	0.2	0.2	**0.2**	0.3	0.1	0.0	0.0	0.0
Trifolium repens L.	2.1	**2.9**	3.8	2.9	**2.8**	2.7	5.8	**5.2**	4.6	2.7	**2.4**	2.1	4.1	1.2	4.1	0.4
Ranunculus repens L.	2.6	**3.9**	5.3	3.2	**3.7**	4.3	1.5	**3.1**	4.8	2.5	**2.8**	3.0	0.4	0.2	1.4	0.8
Taraxacum officinale WEB.	1.8	**1.3**	0.8	1.3	**1.2**	1.0	3.5	**2.3**	1.2	1.6	**1.1**	0.5	1.1	1.0	2.0	1.8
Ranunculus acris L.	1.0	**1.3**	1.6	1.3	**1.6**	1.8	0.6	**1.0**	1.5	0.7	**0.9**	1.2	0.1	0.2	0.8	0.2
Leontodon autumnalis L.	0.8	**0.5**	0.3	0.6	**0.6**	0.7	1.3	**0.9**	0.5	1.1	**0.9**	0.7	0.2	0.1	0.2	0.2
Rumex acetosa L.	0.6	**0.4**	0.3	0.5	**0.5**	0.6	0.4	**0.3**	0.2	0.1	**0.1**	0.2	0.5	0.3	1.2	1.0
Cardamine pratensis L.	0.2	**0.1**	0.1	0.3	**0.2**	0.1	0.8	**0.6**	0.3	0.1	**0.2**	0.3	0.8	1.2	0.7	0.6

No figure means "species not found".

I = continuous grazing without post-grazing treatment.
II = - do - with - do -
III = rotational grazing, low N-application.
IV = - do - high - do -

A = 3-week cutting, low N-application.
B = - do - high - do -
C = 5-week cutting, low - do -
D = - do - high - do -

TABLE 2. Frequency percentages of the different species per treatment. Data are averages of five analyses in the autumn 1956 and in the springs 1958 to 1961. For the grazed plots the mean of the two plots per treatment is shown in bold print. The data of the separate plots are shown in ordinary print in the same columns; the left-hand figures refer to plots 1 to 4, the right-hand figures to plots 5 to 8 in FIG. 1. For explanation of symbols see TABLE 1.

Species	Grazing treatment												Cutting treatment			
	I			II			III			IV			A	B	C	D
Lolium perenne L.	74	**76**	77	84	**85**	85	85	**86**	87	95	**91**	86	62	69	68	77
Holcus lanatus L.	68	**63**	58	59	**66**	72	53	**55**	57	51	**51**	52	94	96	95	95
Poa trivialis L.	81	**85**	88	85	**87**	90	86	**85**	85	80	**84**	88	94	94	85	87
Agrostis stolonifera L.	53	**62**	70	53	**57**	61	49	**54**	59	50	**57**	64	60	53	41	28
Festuca rubra L.	64	**39**	14	46	**34**	22	60	**39**	18	36	**23**	10	41	39	52	43
Anthoxanthum odoratum L.	17	**16**	15	16	**18**	20	18	**18**	19	12	**14**	15	29	26	33	25
Festuca pratensis HUDS.	6	**7**	7	7	**10**	13	6	**7**	8	6	**7**	7	7	4	9	9
Cynosurus cristatus L.	12	**11**	11	14	**13**	13	21	**17**	14	15	**13**	10	17	15	13	12
Agrostis tenuis SIBTH.	13	**15**	16	15	**16**	17	14	**12**	10	9	**6**	3	28	33	13	7
Alopecurus geniculatus L.	1	**5**	8	4	**6**	9	0	**3**	6	4	**6**	8	2	2	4	4
Poa pratensis L.	13	**9**	5	9	**9**	9	15	**11**	6	8	**7**	5	15	17	14	18
Phleum pratense L.	2	**5**	8	5	**7**	8	3	**5**	7	2	**4**	7	9	6	8	5
Alopecurus pratensis L.	3	**3**	2	2	**5**	8	0	**2**	4	1	**2**	4	6	1	2	5
Poa annua L.	2	**4**	5	2	**3**	4	2	**3**	3	6	**6**	6	1	1	1	0
Glyceria fluitans R. BR.		**1**	1	1	**1**	2	0	**0**	1	1	**1**	2				1
Trifolium repens L.	30	**40**	49	44	**43**	41	55	**55**	55	42	**42**	42	46	21	54	25
Ranunculus repens L.	28	**41**	53	38	**45**	52	21	**32**	43	32	**37**	42	6	3	32	19
Taraxacum officinale WEB.	33	**23**	13	19	**18**	17	35	**30**	26	29	**22**	14	28	27	33	23
Ranunculus acris L.	16	**17**	18	15	**15**	15	15	**15**	15	14	**16**	17	7	4	16	6
Leontodon autumnalis L.	10	**8**	6	11	**10**	8	19	**14**	10	11	**10**	8	2	3	5	7
Rumex acetosa L.	8	**7**	5	5	**5**	5	10	**8**	5	6	**5**	3	13	12	24	21
Cardamine pratensis L.	12	**12**	11	19	**15**	11	15	**13**	11	13	**10**	7	32	38	29	22
Bellis perennis L.	10	**8**	6	4	**5**	5	8	**6**	5	6	**6**	7	2	4	4	2
Cerastium holosteoides FR.	4	**4**	4	5	**3**	1	4	**3**	2	2	**2**	2	12	4	2	1
Plantago lanceolata L.	2	**1**		1	**0**		3	**2**			**0**	1	0		1	0

a certain treatment depends on the joint reaction of the other species. Hence in this paper the word 'preference' is always used in a relative sense. It means that the treatment considered is more favourable or less unfavourable for a certain species than for species with a lower relative preference.
Unlike the absolute value of the relative preference, the *order* of preference of two (of more) species is not affected by the behaviour of the other species. Owing to the fairly high deviations in the π-values in our case, the orders found are not always significant but are the best estimate.
Some pairs of treatments or conditions will be separately discussed in the following.
In comparing the grazing treatments (TABLE 3) the relative preference is calculated as the logarithmic average of four independent sub-ratios of ${}^{n}P_{a}$ and ${}^{m}P_{a}$. These respectively refer to the average dry-weight percentages with treatment n and m on replicate 1 during the period autumn 1954 to spring 1958, the average dry-weight percentages on replicate 2 during the same period, the average dry-weight percentages on replicate 1 (after changing the treatments) during the period autumn 1958 to spring 1961, and the average dry-weight percentages on replicate 2 during the same period. Logarithms are chosen because they vary according to a linear scale (${}^{nm}\log \pi = 0.44$ indicates an equal preference to treatment n as ${}^{nm}\log \pi = -0.44$ to treatment m). Averaging independent sub-ratios enables us to test the significance of π and its differences. Although this is not quite mathematically exact, some idea of these significances may be obtained from $S_{\log \pi}$ and $S_{\text{diff.}}$, indicating the standard errors of log π and the difference between the log π of two species respectively. Owing to small differences in the method of calculation, the π's obtained from sub-ratios may slightly differ from the corresponding π's calculated directly from TABLE 1.
In the same way, the preference for drier conditions rather than wet ones (TABLE 4) is calculated as the logarithmic average of eight independent sub-ratios, referring to four treatments (I—IV) and two periods (before and after changing). In comparing cutting treatments (TABLES 5 and 6) no significance test was made because of the small number of independent data.
Owing to its unreliability the order of preference was not determined of species contributing less than 3 % to the sward. Where these species show an apparent preference for one or other treatment (TABLES 1 and 2) this will be briefly mentioned without giving exact data.

3.1. Grazing treatments

The relative preference for different grazing treatments is compared in TABLE 3. It can be seen from this and from FIG. 2 and TABLE 1 that in the case of continuous grazing, post-grazing treatment (treatment II *vs.* treatment I) results in a slight, though not significant, improvement in the botanical composition: *Lolium perenne* and *Poa trivialis* increase, whereas most of the less valuable species decrease, especially *Festuca rubra, Holcus lanatus* and *Agrostis stolonifera.* The same is true of some less important species such as *Anthoxanthum odoratum* and *Agrostis tenuis* (TABLE 1). As will be discussed later in this section, the weight percentages of some species are closely related to the moisture content of the soil which decreases regularly from plot 1 to plot 5 (FIG. 1). Since treatment I on replicate 1 (plots 1 to 4) was always situated on a drier part of the field than treatment II, the π-value of *Festuca rubra* may be somewhat underestimated and the π-value of *Poa trivialis* and perhaps of *Agrostis stolonifera* and *Ranunculus repens* somewhat overestimated. The difference

TABLE 3. Order of relative preference of the seven main species for post-grazing treatment as opposed to no treatment with continuous grazing (II *vs.* I), for rotational as opposed to continuous grazing (III *vs.* ½ (I + II)) and for high as opposed to low N-application with rotational grazing (IV *vs.* III). $S_{\log \pi}$ and $S_{\text{diff.}}$ are the standard errors of log π and the difference between the log π of two species respectively.

II *vs.* I			III *vs.* ½ (I + II)			IV *vs.* III		
species	π	log π	species	π	log π	species	π	log π
Lp	1.22	0.09	Tr	1.78	0.25	Lp	1.21	0.08
Pt	1.15	0.06	Lp	1.65	0.22	Pt	1.20	0.08
Tr	1.09	0.04	Fr	1.09	0.04	Ran r	1.03	0.01
Ran r	0.98	—0.01	Pt	0.79	—0.10	As	0.99	—0.00
As	0.88	—0.06	As	0.66	—0.18	Hl	0.67	—0.17
Hl	0.85	—0.07	Ran r	0.56	—0.25	Tr	0.52	—0.28
Fr	0.75	—0.12	Hl	0.38	—0.43	Fr	0.41	—0.39
$S_{\log \pi}$		0.089	$S_{\log \pi}$		0.120	$S_{\log \pi}$		0.071
$S_{\text{diff.}}$		0.126	$S_{\text{diff.}}$		0.169	$S_{\text{diff.}}$		0.101

As = *Agrostis stolonifera* Lp = *Lolium perenne* Ran r = *Ranunculus repens*
Fr = *Festuca rubra* Pt = *Poa trivialis* Tr = *Trifolium repens*
Hl = *Holcus lanatus*

between rotational grazing and continuous grazing is considerable even when the total nitrogen application per year is the same (treatment III *vs.* treatments I and II). *Holcus lanatus* in particular is favoured by continuous grazing. The same is true of *Ranunculus repens, Agrostis stolonifera, Poa trivialis* and *Agrostis tenuis. Lolium perenne* and *Trifolium repens* are favoured by rotational grazing (TABLE 3). The latter may also be true of *Taraxacum officinale* and *Cynosurus cristatus* (TABLE 1).

In rotational grazing the only species favoured by high nitrogen application are *Lolium perenne* and *Poa trivialis* (treatment IV *vs.* treatment III); a preference for low nitrogen application is shown by *Festuca rubra, Trifolium repens, Holcus lanatus* and the less important species *Anthoxanthum odoratum, Agrostis tenuis* and *Taraxacum officinale.* Since treatment III on replicate 1 was always situated on a drier part of the field than treatment IV, the π-value of *Festuca rubra* may be somewhat too low and those of *Poa trivialis, Agrostis stolonifera* and *Ranunculus repens* somewhat too high.

A very noticeable feature is the great difference in dry-weight and frequency percentages between the two replicates of some species (left rows *vs.* right rows of the grazing treatments in TABLES 1 and 2). As already suggested, this is probably due to the difference in the soil-moisture content of the two replicates. When we divide the moisture content of the soil into dry, normal moisture content, moist and wet, we find that the front part of the field has a fairly normal moisture content and is sometimes moderately susceptible to drought, whereas the rear part of the field is moist and sometimes wet. In TABLE 4 the relative preference is presented in the order of drier to wetter conditions. A strong preference for drier conditions is shown by *Festuca rubra. Lolium perenne, Trifolium repens* and *Holcus lanatus* are fairly indifferent, whereas *Poa trivialis, Agrostis stolonifera* and *Ranunculus repens* prefer wetter conditions in increasing order. Of the less important species drier conditions are preferred by *Cynosurus cristatus, Taraxacum officinale, Poa pratensis, Leontodon atumnalis* and *Cardamine pratensis,* and wetter conditions by *Alopecurus geniculatus, Phleum pratense, Ranunculus acris* and probably by *Festuca pratensis.*

Dry *vs.* wet		
species	π	log π
Fr	6.33	0.80
Lp	1.02	0.01
Tr	1.00	0.00
Hl	0.86	—0.07
Pt	0.72	—0.14
As	0.69	—0.16
Ran r	0.48	—0.32
$s_{\log \pi}$		0.060
$s_{\text{diff.}}$		0.085

TABLE 4.
Order of relative preference of the seven main species for drier as opposed to wet conditions. For explanation of symbols see TABLE 3.

3.2. Grazing *vs.* cutting

A comparison of the grazing treatments as a whole with the cutting treatments as a whole shows that certain species have a distinct preference for grazing and others for cutting. Since the cut plots are situated in replicate 2 of the grazed plots (FIG. 1), only the data of this replicate have been used for comparison (right rows of treatments I to IV in TABLES 1 and 2 *vs.* treatments A to D). The results are presented in TABLE 5. An extreme preference for grazing is shown by *Ranunculus repens.* This

Grazing *vs.* cutting		
species	π	log π
Ran r	6.26	0.80
As	1.98	0.30
Lp	1.97	0.29
Tr	1.35	0.13
Pt	1.21	0.08
Hl	0.42	—0.37
Fr	0.19	—0.72

TABLE 5.
Order of relative preference of the seven main species for grazing as opposed to cutting (¼ (I + II + III + IV of replicate 2) *vs.* ¼ (A + B + C + D)). For explanation of symbols see TABLE 3.

cannot be due to its avoidance by the cattle as the preference also occurred on the rotationally grazed plots, which were very intensively grazed and topped after each grazing. Grazing is also preferred by *Agrostis stolonifera* and *Lolium perenne.* TABLE 1 shows that the behaviour of *Trifolium repens* and *Poa trivialis* depends on the treatment within the group of grazing or cutting. *Trifolium repens* prefers grazing mainly with high N-application. *Poa trivialis* prefers grazing to 5-week cutting, but is indifferent with respect to 3-week cutting or it may have a slight preference for the latter. An extreme preference for cutting is shown by *Festuca rubra,* whereas cutting is also distinctly preferred by *Holcus lanatus.* As to the less important species, grazing is preferred by *Alopecurus geniculatus, Poa annua, Ranunculus acris, Leontodon autumnalis, Glyceria fluitans* and perhaps *Festuca pratensis,* and cutting by *Anthoxanthum odoratum, Poa pratensis, Rumex acetosa, Cardamine pratensis* and *Agrostis tenuis.*

3.3. Cutting treatments

Apart from the preference of a species for cutting or grazing it may be considered whether in the cutting there is a preference for 3-week or 5-week cutting (treatments A and B *vs.* treatments C and D) and for high or low nitrogen application (treatments B and D *vs.* treatments A and C). This is shown in TABLE 6. A preference for 3-week cutting is shown by *Agrostis stolonifera, Poa trivialis* and *Trifolium repens,* and of the less important species perhaps by *Cardamine pratensis.* 5-week cutting is preferred by *Ranunculus repens, Festuca rubra* and *Lolium perenne,* and

TABLE 6. Order of relative preference of the seven main species for 3-week as opposed to 5-week cutting ($\sqrt{AB}$ *vs.* $\sqrt{CD}$) and for high as opposed to low N-application with cutting ($\sqrt{BD}$ *vs.* $\sqrt{AC}$). For explanation of symbols see TABLE 3.

3-week *vs.* 5-week cutting			High N *vs.* low N		
species	π	log π	species	π	log π
As	2.83	0.44	Lp	1.25	0.10
Pt	2.32	0.37	Pt	1.10	0.04
Tr	1.74	0.24	Fr	1.09	0.04
Hl	0.90	—0.05	Hl	1.03	0.01
Lp	0.72	—0.14	As	0.78	—0.11
Fr	0.72	—0.15	Ran r	0.64	—0.20
Ran r	0.27	—0.56	Tr	0.17	—0.76

of the less important species by *Rumex acetosa, Festuca pratensis, Poa pratensis* and *Taraxacum officinale.* An extreme preference for low nitrogen application is shown by *Trifolium repens.* Other species preferring low nitrogen application are *Ranunculus repens, Agrostis stolonifera, Anthoxanthum odoratum* and *Agrostis tenuis.* Only *Lolium perenne, Poa pratensis* and perhaps *Alopecurus geniculatus* are favoured by a high nitrogen application.

3.4. Influence of the weather

FIG. 2 and 3 show that the extremely dry summer of 1959 and to a less extent the dry summer of 1955 were relatively favourable for the dominant species *Lolium perenne* and (on the cut plots) *Holcus lanatus.* Other species, especially *Poa trivialis,* and also *Festuca rubra* and *Agrostis stolonifera* decreased under these conditions. In the wet and rather cool season of 1956 the reverse was observed. The frequency percentages are affected in a similar way but to a less extent. For example, the average dry-weight percentages of *Poa trivialis* on the grazed plots in spring 1959, 1960 and 1961 were 20 %, 1½ % and 10 %, respectively. The corresponding frequency percentages were 94 %, 59 % and 88 %.

3.5. Growth rhythm

The growth rhythm varies for different species. Some species contribute most to the sward in spring, others in summer or autumn. This is most regular for white clover and some herbs. White clover has its maximum growth in summer (FIG. 2 and 3), like *Leontodon autumnalis.* Most of the other herbs have their maximum in spring, *e.g. Taraxacum officinale, Ranunculus repens* and *Rumex acetosa* (derived from the original data).

3.6. Moles

In many years there were a large number of moles in the experimental area. It was observed that their number was much greater in continuously grazed plots than in rotationally grazed plots. The number of moles in the rotationally grazed plots was greater in those receiving a low nitrogen application than in those with a high nitrogen application. Details will be given in a subsequent paper.

4. Discussion

As already stated, some idea of the significance of the relative preferences and their order may be obtained from $S_{\log \pi}$ and $S_{\text{diff.}}$ When $2S$ is used as a standard of significance only a small number of π's and their differences are found to be significant. The following examples show that this standard is not always decisive. According to the $2S$-standard the preference of *Lolium perenne* for rotational grazing rather than continuous grazing is not assumed to be significant (TABLE 3). But it is obvious from FIG. 2 that this preference is almost certain since with one exception (spring 1960) the dry-weight percentage of *Lolium perenne* is continuously higher with rotational grazing. The same is true of the preference of *Lolium perenne* for high N-application rather than for low N-application with grazing (TABLE 3 and FIG. 2).

By comparing the different tables we may establish which factor has the greatest effect on the botanical composition. The contrast in botanical composition is greatest with grazing *vs.* cutting. The next two factors in importance are the moisture content of the soil and the frequency of cutting. It is remarkable that in the case of grazing the system of grazing (rotational *vs.* continuous grazing) has a greater effect than the difference in N-application (amounting to 70 kg N/ha). Similarly with cutting, the frequency of cutting has a greater effect than the difference in N-application.

A comparison between the response of one species undergoing different treatments or conditions shows that the tables do not always correspond. For instance, the order of preference of *Ranunculus repens* and *Festuca rubra* for low N-application is different with grazing and cutting. This may be due to an interaction between management (grazing or cutting) and N-application, but is more probably the result of unreliability of the orders of preference found. Besides $S_{\log \pi}$ and $S_{\text{diff.}}$ the data in TABLES 1 and 2 and FIG. 2 and 3 may help to provide a good estimate of the π-values.

In general there is a good agreement between our results and those reported in the literature (GEERING, 1941; VOISIN, 1960; KRUIJNE and DE VRIES, 1963; DE VRIES and KRUIJNE, 1960). A few controversial points will be discussed here. According to DE VRIES and KRUIJNE (1960) of all the good grasses *Phleum pratense* shows the best response to nitrogen application. In our experiment *Phleum* was not favoured by nitrogen application either with grazing or cutting. It is reported by DE VRIES and KRUIJNE that when grazing is compared with haying, *Cynosurus cristatus* and *Agrostis tenuis* prefer grazing, whereas *Festuca rubra* prefers haying. TABLE 1 shows that with frequent or fairly frequent cutting instead of haying, *Cynosurus, Agrostis tenuis* as well as *Festuca rubra* prefer frequent cutting to grazing. This may indicate that the height of the sward (light supply) is decisive for *Cynosurus* and *Agrostis tenuis,* and for *Festuca rubra* the effect of grazing as such. Although *Cardamine pratensis* is reported to prefer wet or moist conditions (KRUIJNE and DE VRIES, 1963) we found this species more frequent on the drier part of the field. According to DE VRIES (1958) *Lolium perenne* is less resistant to wet conditions than *Cynosurus cristatus.* In our experiment the converse is apparently true.

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