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**NITROGEN EFFECT ON THE HERBAGE PRODUCTION OF GRASSLANDS ON
DIFFERENT SITES**

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Summary

With intensive grassland husbandry in the Netherlands many growth factors are constant, particularly the chemical fertility of the soil and the botanical quality of the permanent grassland. But two factors still vary within a wide range: nitrogen fertilization and the water-supply status of the soil.

This paper describes an investigation, started in 1964, in which the interaction of the above mentioned factors were studied in the weather conditions prevailing in the Netherlands. The selection of the sites was based on soil- and vegetation-types. The results are discussed in relation to other nitrogen-response investigations in the Netherlands.

Introduction

The results of an annual dry-matter-yield investigation on about 50 grasslands on different sites, with a standardized yield and fertilizer system, during the period 1945/58 (10) gave rise to 2 conclusions. Firstly, within the same year, the annual dry-matter yield may vary 100 %. Secondly, the same variation was found in the average annual yield of the group of fields during the period of the investigation.

This indicates that differences in site and weather conditions alone may cause wide variations in the annual dry-matter yields.

Since the chemical soil fertility for plant production on grassland is generally sufficient in the Netherlands, the production differences are mainly caused by weather conditions, nitrogen applications and the physical properties of the soil type (1).

It will be interesting, therefore, to investigate the N effect on the yield within different ranges of N-application and the interaction of site (indicated by the herbage) and weather conditions. A good number of experimental fields is required for this kind of research. Since cattle experiments are too expensive, the gross-production method was considered more suitable.

In this method, the cutting frequency, also the growth stage of the herbage, influence the nitrogen response (7, 8, 9). The works referred to show, e.g. that a pasture cut (average of 1275 kg d.m./ha) has a N response of about 10 kg d.m./kg N and a hay cut (average of 4480 kg d.m./ha) of about 25 kg d.m./kg N (within a range of 0—40 kg N/ha). Cutting 4 to 8 times a year shows responses of 8 and 4 kg d.m./kg N (0—320 kg N/ha/year), respectively. In autumn a cut of about 1500 kg d.m./ha (with 25 kg N/ha) compared to a cut of about 2600 kg (4 weeks later) shows responses of 2.9 and 17.7 kg d.m./kg N within the range 25—125 kg N/ha.

With the same cutting frequency, differences in N effect are established during the season (4). The highest responses are in May and June (average of 7 years). On sand 18—22 kg d.m./kg N, on peat 12—18 kg d.m./kg N

within the range of 0—60 kg N with the 1st cut and 0—35 kg N with the 2nd cut. In late summer the response on peat drops to about 2 kg d.m./kg N and on sand to 10—14 kg d.m./kg N. These facts, as well as the harvesting system in practice, suggested a cutting and N-distribution scheme, described later on. Roughly, the higher response of an older cut is taken into account by including a hay cut and one or two silage cuts in the scheme. In N distribution, the higher response at the beginning of the growing season is taken into account by applying a rather liberal N-treatment of the first cut. One could say that an optimal cutting system is applied.

In the Netherlands, systematic research on the N-response on different soils has already been carried out for some years (11) on grassland with a good management status. The average responses of the total annual production (1960—63) with the same cutting system were: on sand 16.7 kg, on clay 15.0 kg and on peat 10.0 kg d.m./kg N (within a range of 0—100 kg N/ha/year).

Besides this research to study the influence of soil on the N-response, Bosch (3) compiled the data from N experiments on different soils with various treatments during the last 30 years. He composed a provisional scheme to show the net N-effect. No differences are shown within a range of 0—100 kg N/ha/year. Above 200 kg N/ha/year the response on peat was considerably lower than that on sand and clay.

Since constituents like sand, peat and clay only very roughly characterize the site, continued research into this topic seems important.

Experimental procedure

For this study on the N effect, 8 different sites were selected. The soil type and water-supply status, the latter indicated by the vegetation (2), were varied. Old permanent grassland with a good management status was used. In the climatic conditions and grassland-husbandry system of the Netherlands, this results in a grassland with a high percentage of species like *Lolium perenne*, *Festuca pratensis*,

Pbleum pratense, *Poa trivialis* and *Poa pratensis*. The proportion of the individual species in this group changes with the site, especially with differences in the water supply. In extreme water-supply conditions, even with a good management status, the percentage of this group of grass as a whole will decrease (1) and species like *Agrostis stolonifera* or *Agrostis tenuis* will become more important. A short description of the 8 sites follows.

a) Low wood-peat soil. The top layer of the selected type of this soil group always contains some clay. Transition to the peat sub-soil is very gradual. In this soil type two variants were selected with a different water-supply status, based on the botanical composition.

a₁) None or only sporadic indicators are found of a poor drainage status. This drainage condition is found in a minority of cases on this soil type.

a₂) More than 15 % of indicators are found showing poor drainage. In most years this site is wet for shorter or longer periods, and grazing is very difficult. The greater part of this soil type belongs to this drainage condition.

b) Low peat soil with a rather heavy clay cover of about 40 cm. The topsoil is very rich in organic matter and does not differ much from a). However, 10—15 cm below the surface the clay cover grows more heavy and the lower part of it is very heavy and often sticky.

The soil types a) and b) together cover about 100,000 ha in the Netherlands and are almost continuously under permanent grassland.

The drainage conditions b₁ and b₂ were selected by the same principles as a₁ and a₂,

a third (b₃) was also studied. The drainage condition on this sub-type b₃ fluctuates more widely from wet to somewhat dry during the growing season (depending on the year) (Table 1).

c) Low sandy gley soils with finely granulated sand, sometimes a little loamy. In our series the organic-matter content in the topsoil is always rather low (naturally or through deep ploughing). Again, two drainage types were selected, based on the vegetation:

c₁ well drained; c₂ poorly drained.

d) High and moderately high podzolized sandy soils, finely granulated. Usually, drought-susceptible grassland is found on this soil type, especially old permanent grassland. The latter was studied and contained more than 40 % of those plant species which indicate drought conditions.

Table 1 shows the trend in the depth of the ground-water table during the season. The average depth of the groundwater table does not decrease only on a₂ and b₂, but the fluctuation in the periods is wider than a₁ and b₁. On the wet sand soils (c₂) this is even more evident, though on a lower level. Sometimes the water table in peat soil is at a level of 0—10 cm for some days, and at 40—50 cm some days later. This is not found in sand and clay on peat soils.

Three nitrogen-experiment fields were set out on each of these 8 sites. In all there were 24 fields.

The size of each experimental field was such that only $\frac{1}{5}$ was cut each year, therefore the influence of cutting on the sward was small. The uncut part of each N plot received the same N treatment and total annual application, but it was used by the farmer.

The scheme in Table 2 is closely followed

Table 1. Depth of the ground-water table in cm below the surface (1964). Averages of the indicated periods for the different sites

	1 III—30 IV	1 V—30 VI	1 VII—31 VIII	1 V—30 VI
a ₁	46	57	55	44
b ₁	51	53	63	48
b ₃	26	66	74	45
a ₂	22	39	42	26
b ₂	23	34	50	30
d	107	141	170	173
c ₁	55	98	122	129
c ₂	25	61	69	72

Table 2. Total N-application per year, and the distribution over the different cuts

Total N kg/ha/year	Percentage of the total N-application applied per cut					
	1	2	3	4	5	6
50	40	10	10	10		
100	40	20	20	10	10	
200	40	20	20	10	10	
300	40	17	14	20	10	
400	40	15	12	18	10	5
500	40	16	12	16	10	6

in applying N. The treatment in kg/ha/year were on peat 0, 50, 100, 200, 300 and 400. On the other sites 0, 100, 200, 300, 400 and 500. The first application in 1964 was in the last decade of March.

The phosphate and potash fertilization was in balance with the results of the soil test and the amount of the herbage harvested.

As already mentioned in the introduction, the cutting frequency was adapted to the N scheme and weather conditions, and to some extent it was a reflection of the grassland management practiced.

The cutting scheme was as follows:

1st cut: a hay cut of about 4000 kg d.m./ha; on treatments with a slow growth rate the stage is decisive;

2nd cut: a pasture cut (in 1964 rather heavy, about 2000 kg d.m./ha);

3rd cut: a pasture cut (about 1600 kg d.m./ha);

4th cut: depending on the N application, a pasture or a silage cut (2500—3000 kg d.m./ha/); with 300 kg N/ha/year and over, usually a silage cut;

5th cut: usually a pasture cut, at the highest N-levels sometimes a silage cut;

6th cut: if possible, a pasture cut.

In this cutting system the zero-N plots were harvested 3 to 5 times and the high-N plots 5 to 7 times during 1964.

Results

This paper deals only with the annual dry-matter and N yields in 1964. Occasionally, the dry-matter yield in 1964 is compared to the figures of 1965. Figure 1 shows an overall picture of the interaction between N application, site and annual dry-matter and N

yield. The diagram method is taken from Frankena *et al.* (6). In that paper it was used to show the influence of N applied at the first cut. Although the annual yield is harvested more complexly, it seems that the same diagram method may be used.

The upper left quadrant in Fig. 1 shows the influence of the annual N-application on the annual dry-matter yield. The first point of interest is the great difference in the annual production without applied N (total variation 5500—9600 kg d.m./ha). A second point is the decreasing effect of N-application on this variation (with about 300 kg N, 10,500—12,500). This effect decreases the total variation, with about 50 % at the level on which the N response is marginal for most of the sites. A third interesting point is that this marginal point moves from left to right (from about 300 kg N to 200 kg N), from the low- to the high-production level. Finally, the different gradients of the lines are mentioned.

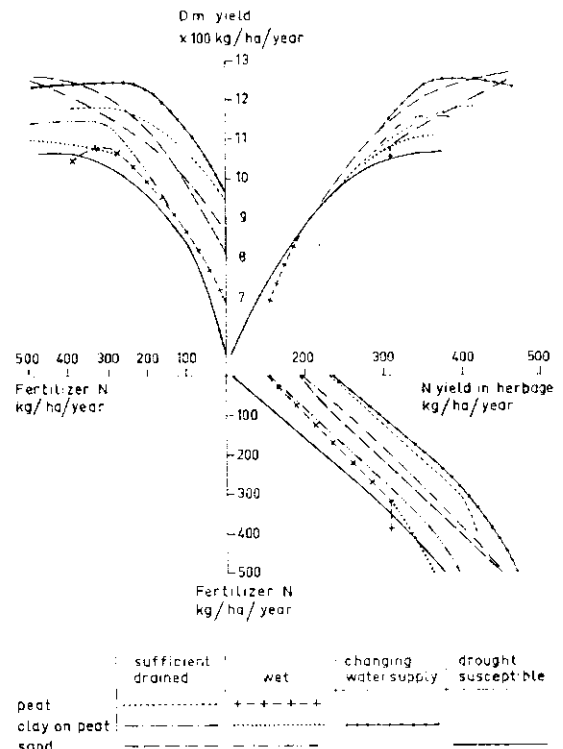


Fig. 1. Effect of fertilizer nitrogen application on dry matter yield and total N absorbed by the herbage. Every line represents the average of 3 experimental fields. All figures apply to annual amounts in 1964.

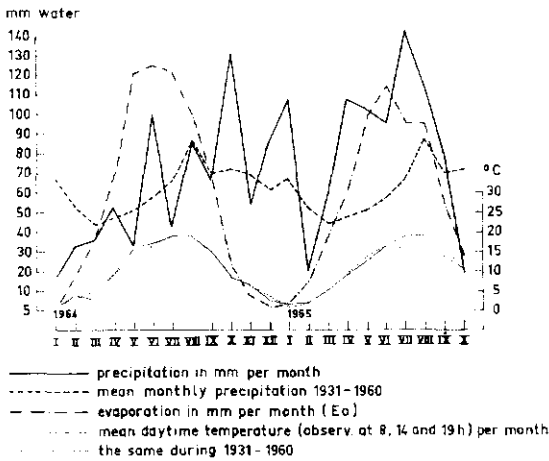


Fig. 2. Weather conditions during 1964 and 1965.

This indicates that there are differences in N effect.

The figures for dry-matter production in 1965 from the same sites present a somewhat different picture. This is caused by the different weather conditions in 1964 and 1965. Figure 2 shows these differences. In 1965, the wetter and somewhat colder growth period for the first cut is characteristic, as well as the higher precipitation and lower evaporation (Eo) in summer.

In 1964 some drought influence was established in the regrowth of the first cut and at the end of July. This corresponds with the lowest points in the precipitation curve during the 1964 growth period (combined with high evaporation).

In 1965, the differences in weather conditions caused a somewhat higher production level on most of the sites. The drought-susceptible sandy soil showed a much higher production level (over 2500 kg d.m./ha higher with no N). The figures for 1965 suggested that on most sites the N-effect is marginal with 300 kg N/ha/year or even higher rates.

Wet peat is the only exception, with about 150 kg N. Table 3 represents the N-responses within the range 0—200 kg N/ha/year in 1964 and 1965.

The lowest N-effects (average of 9 observations 11.5 kg d.m./kg N) in both years were found on the sufficiently drained peat, with average dry-matter yields of 8500—9500 kg d.m./ha/year with no N.

The highest (average of 6 observations 18.8 kg d.m./kg N) are found on sandy soils, in all water-supply classes, especially in 1965. The production level with no N for this highest N-response class varies from 5500—8200 kg d.m./ha/year.

If the highest and the lowest group of N-effects are compared in these 2 years, there is a great difference (7.3 kg d.m./kg N), suggesting a negative correlation with the no N production level. The same conclusion is to be found in the literature (4, 7 and 11).

In studying the remaining group of N-responses (between 14 and 16), it is found that these responses occur on all sites, except for the drought-susceptible sand and the well-drained peat soils. The average no-N yields in this remaining group varied from 7000—96000 kg d.m./ha/year.

In studying the 2 quadrants on the right side in the figure it is seen that the N-yield and the dry-matter yield of the herbage are plotted against increasing N-applications. Roughly, there is a rectilinear correlation between the dry-matter yield of from 5500 to 9500 kg d.m./ha/year and the N-yield of from 105 to 225 kg N/ha/year. Above this level the correlation between the N-uptake and dry-matter yield is influenced by other growth factors, depending on the site.

It is also seen that there is a great difference in N-uptake without fertilizer N on the various sites. The total variation is 107—235 kg N/ha/year of the averages in 1964.

An indication is also obtained regarding the

Table 3. Average N-effect in kg d.m./kg N within the fertilizer range 0 to 200 kg N/ha/year on each site during 1964 (figures for 1965 in brackets)

	Sufficiently drained	Wet	Fluctuating water-supply	Drought susceptible
Peat	13.5 (10.3)	13.9 (14.4)		
Clay on peat	10.7 (11.4)	15.6 (13.9)	15.7 (13.9)	
Sand	15.8 (12.7)	14.7 (18.8)		19.0 (14.4)

influence of the fertilizer N applied on the additional N-uptake by the herbage. On a number of sites this additional N-uptake was about 60 % of the amount applied. On the wet sites, and some others with higher applications, this percentage decreased to 45—50 % (12).

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