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THE EFFECT OF NITROGEN ON A CLOVER/GRASS MIXTURE AND ITS APPLICATION IN FARMING PRACTICE

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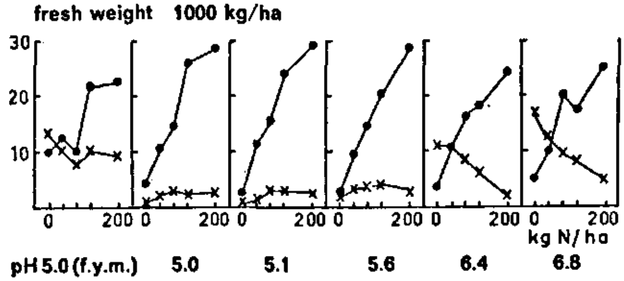
Fig. 1. The effect of soil pH (H_2O) and increasing amounts of nitrogen on yield and composition of the first cut of a mixture of perennial ryegrass and red clover. On plot pH 5 (f.y.m.) the effect of a dressing of farmyard manure is shown; see also plates 7 and 8.

•—• *perennial ryegrass*
X—X *red clover*



Introduction

It is well known that leguminous plants play an important part in the nitrogen economy of swards. In a number of important farming areas the provision of combined nitrogen is left entirely to legumes, which demonstrates the economic significance of these plants. The output of a grass/clover pasture will, occasionally, need to be increased with the aid of fertilizer nitrogen. In that event we will need to know to what extent fertilizer nitrogen affects the role of clover as a nitrogen source and what effect it has on competition between the clover and the grass, that is to say on the botanical composition of the sward. Competition between grass and clover as affected by applying nitrogen fertilizer may best be elucidated with the aid of an example drawn from a field trial laid down to investigate the effect of soil pH and various rates of nitrogen on the yield and composition of a mixed crop of red clover and perennial ryegrass.

Nitrogen response of a clover/grass mixture

Red clover and perennial ryegrass were sown in alternate rows on a series of test plots in which the pH (H_2O) varied from 5.0 to 7.0. Each test plot had increasing quantities of nitrogen applied to it, viz. 0, 40, 80, 120 and 200 kg N per ha. Grass and clover were harvested separately. The yield and botanical composition at the first cut are depicted in *fig. 1*. The clover was not inoculated.

A similar trial was carried out on the same series of plots in another year, but with this difference: one half of each plot was sown to red clover, the other half to perennial ryegrass, i.e. 2 monocultures were grown instead of one mixed stand. The results obtained at the first harvest in this trial are depicted in *fig. 2*.

The differences are striking, particularly as regards the growth of the clover on the low-pH plots. In the mixed stands there was practically no yield from the red clover on the low-pH plots. At higher pH levels the clover grew much better, though its yield was negatively correlated with the amount of nitrogen applied. These effects are clearly demonstrated in the accompanying photographs (plates 1-6).

Where clover and grass were grown in pure stands, however, the response to fertilizer nitrogen of the clover on the low-pH was practically the same as that of the grass.

It is evident that the poor growth of the clover component of the mixture on the low-pH plots was in some way connected with soil pH, yet the low pH of the soil was *not directly* to blame for the poor develop-

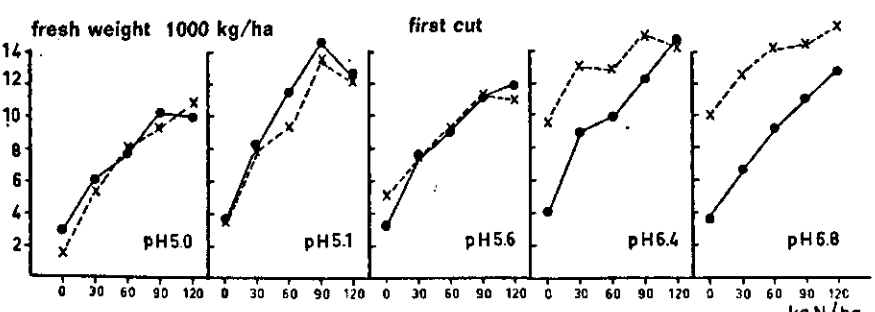


Fig. 2. The effect of soil pH (H_2O) and increasing amounts of nitrogen on the yield from the first cut of a monoculture of perennial ryegrass and red clover.

•—• *perennial ryegrass*
X—X *red clover*

Plates 1-6. Effect of pH and rates of nitrogen on the yield and composition of a red clover/perennial ryegrass mixture. Each photo shows a comparable portion of the test plot; the third cut has been photographed with the no-N treatment in the centre and a high-N treatment to the right of it. The relevant soil-pH (H_2O) is shown alongside each of the photographs.

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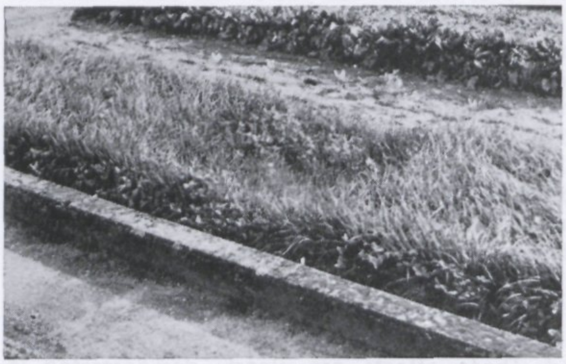


pH 4.7

2

pH 5.0

3

pH 5.1

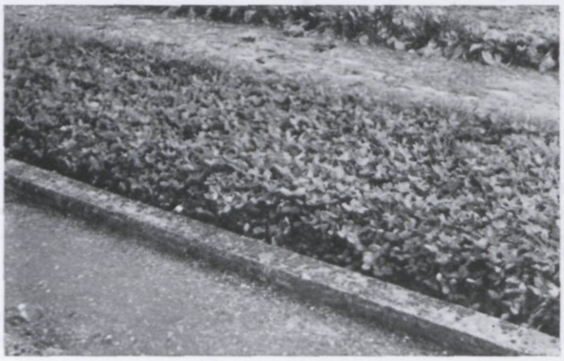
4

pH 5.8

5

pH 6.6

6



pH 7.0

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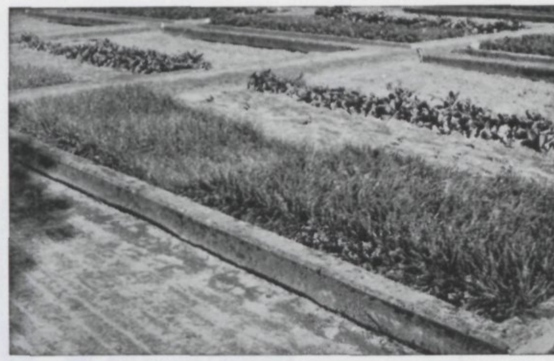


Plates 7-8. The effect of farmyard manure on clover development. The soil pH is 5.0 on both plots; the plot on the left was given a heavy dressing of farmyard manure a few years earlier, while the plot on the right received none.

ment of the clover, since clover grown as a pure stand on the same test plots developed reasonably well. We must therefore ascribe the poor development of clover grown in the mixed stands at the low soil pH to the competitive effect of the perennial ryegrass, particularly for fertilizer nitrogen. The English investigator WALKER [18] found that 95% of ^{15}N-labelled mineral nitrogen absorbed by a mixed stand of clover and grass was taken up by the grass. The same investigator [19] further pointed out that grasses in mixture with clover also possess a greater capacity to absorb K, P, S and trace elements than the clover does.

If we now return to the assessment of our experimental results, we should therefore assume that most of the fertilizer nitrogen applied to the mixed stand of red clover and perennial ryegrass grown on the low-pH plots was taken up by the grass; the result was that the clover suffered from nitrogen deficiency (which was clearly visible), particularly as the root nodules which would normally have been able to satisfy the nitrogen requirements of the clover were not formed immediately because the soil was so acid (see table 1).

Table 1. **The effect of soil pH(H_2O) and increasing amounts of nitrogen on nodulation of red clover,** ***expressed as mg nodule-DM per g top-DM***

N-dressing	soil-pH(H_2O)					
kg/ha	4.7	5.0	5.1	5.8	6.6	7.0
0	18.8	0	68.2	41.6	44.2	41.1
40	0.3	0	18.8	23.4	40.6	29.7
80	0	0	4.9	38.2	31.1	48.3
120	16.4	0	1.3	15.0	21.2	20.6
200	0	0	0	1.2	11.5	12.6

The grass grew up above the clover, causing shading and consequent depression in growth.

In the mixture on neutral soil the clover already had a slightly better start; furthermore, root nodules were quickly formed, releasing the clover from its dependence on mineral nitrogen and enabling it to compete well with the grass. In the high-pH plots the contribution of grass to the total yield increased with increasing rates of fertilizer nitrogen, whereas the amount of clover declined; this seems to be a clear instance of competition for space, since where grass is growing there is no room for clover.

In the above trial we have dealt with an example of competition between red clover and grass. We may assume that as far as competition for mineral nitrogen is concerned, similar rules will apply to mixtures of white clover and grass; however, as a consequence of its creeping growth habit white clover will endure still stiffer competition from grass than will red clover with its upright growth habit.

The effect of nitrogen on clovery grassland

We are now in a better position to describe what happens when nitrogen is applied to a sward containing a high proportion of clover. A large share of the applied nitrogen is taken up by the grass; a smaller proportion is taken up by the clover without it having any effect on clover growth [3], since, as might be expected, the uptake of mineral nitrogen results in a simultaneous depression of nitrogen fixation [1, 2, 15]. The consequence is that the growth of the grass is strongly stimulated in comparison with that of the clover, causing shading and suppression of the clover. On top of this the increased vigour of the grass growth leads to additional competition for water and for other nutrients.

HOLMES and ALDRICH [10] have depicted the response of a clover-rich sward diagramatically in *fig. 3.* The diagram indicates that applying nitrogen to grassland rich in clover results in the replacement

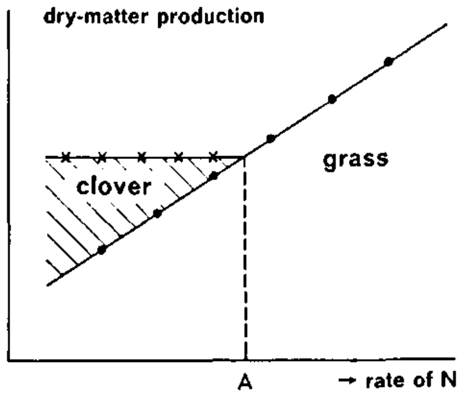


fig. 3

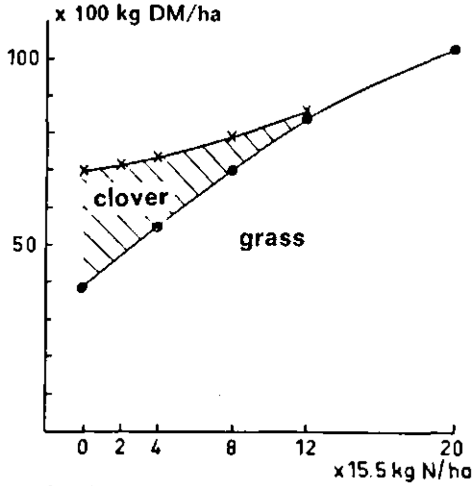


fig. 4

Fig. 3. The response of grassland rich in clover to applied nitrogen, diagrammatic representation according to Holmes and Aldrich.

Fig. 4. The response of grassland rich in clover to applied nitrogen, according to data from a 3-year trial by Linehan and Lowe.

of clover by grass without materially affecting the total dry-matter yield. (It frequently happens that the increasing rate of N results in a decrease in the yield of protein per unit area, since the N-content of grass is lower on average than that of clover). Only above a given level (marked A in fig. 3) does applied N lead to an increase in total yield of dry matter. The position of A is determined by the percentage of clover in the sward.

According to WALKER [17] reductions in the yield of a grass/clover sward are observed now and again under practical farming conditions after applying a moderate dressing of N, and the yield increases again only when higher rates of nitrogen are applied.

In connection with the Holmes and Aldrich diagram (fig. 3), fig. 4 displays the relationship in a 3-year farm-scale trial by LINEHAN and LOWE, cited by WALKER [19], between the rate of applied nitrogen and the yield and botanical composition of the harvested herbage. The gross response to nitrogen was very slight, the response of the grass component was almost linear, while the proportion of white clover steadily declined with increasing rates of applied N; however, the response of the clover differed favourably from that depicted in the Holmes and Aldrich diagram.

Fig. 5 depicts the total yield during the growing season in a trial to in vestigate the effect of amount of applied nitrogen and pH on the yield and composition of a red clover/perennial ryegrass mixture [5]. Three cuts were taken in this trial, of which the first and the third cut received the amounts of nitrogen shown, while the second cut was not fertilized. On the low-pH plots, where the sward consisted almost entirely of grass, a strong linear response to nitrogen was observed. On the high-pH plots, where the percentage of clover in the sward was high, the total response to nitrogen was only slight. The strong response of the grass to nitrogen was in this instance balanced by stronger growth of the clover at the lower levels of N. Despite the difference in experimental layout and the fact that it was red clover which was used in our trials, the qualitative similarity with the experimental results of Linehan and Lowe is striking.

Clover as a nitrogen source

Nitrogen fixed by clover, as well as nitrogen applied as artificial fertilizer, can have important effects on the changes in the botanical composition of a clovery sward. It is a well known fact that grass growing in association with clover benefits from atmospheric nitrogen fixed by the clover. There has been a great deal of discussion on the subject of whether this nitrogen is excreted by the legume root system during active growth or whether it is rendered available only when the roots and stubbles die.

The well known Finnish investigator VIRTANEN [15,

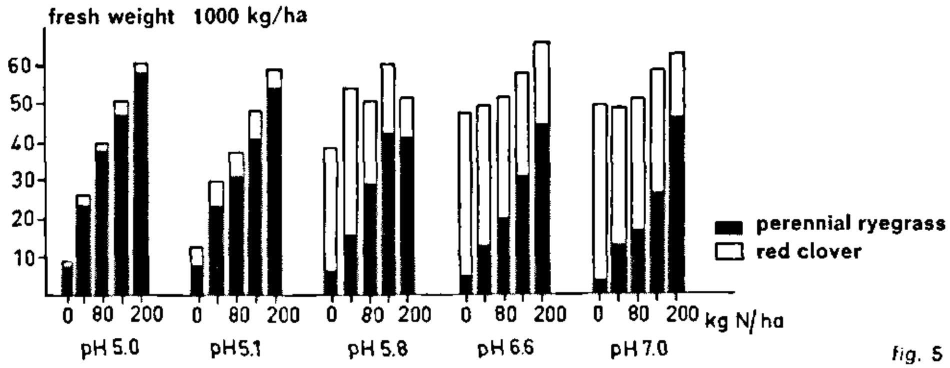


Fig. 5. The effect of soil pH(H_2O) and increasing amounts of nitrogen on the annual yield of a perennial ryegrass/red clover mixture. The nitrogen was applied to the first and third cuts only.

16], and some decades earlier the American investigator LIPMAN [12], are so far the only ones to have detected significant excretion of nitrogen-containing compounds during the active growing phase of the legume. Numerous workers have repeated the trials, and yet some of them have found only a slight nitrogen response during the phase of active growth, and most workers no effect at all.

This point has led to us carrying out yet another trial [6] in which the action of lucerne, red clover and white clover on grass was investigated in pots in which one row of grass was sown adjacent to one row of clover or lucerne. The growth of this grass was compared with that of grass plants whose root systems were separated from those of the legume by means of a sheet of glass.

The clover and the grass were sown at the beginning of June; the legumes were cut on 10 September and 2 December, the grass was given its third cut on 10 September and its fourth cut on 2 December. On 2 December the aboveground parts of the legume were removed completely in order to kill the roots. The grass was allowed to grow on.

The grass was analysed for nitrogen content and the amount of nitrogen contributed by the legumes was calculated from the difference in nitrogen content of grass grown with and without a sheet of glass separating the root systems. The analytical results are shown in table 2.

Table 2. **Effect of various legumes on the amount of nitrogen contained in grass growing in association with them**

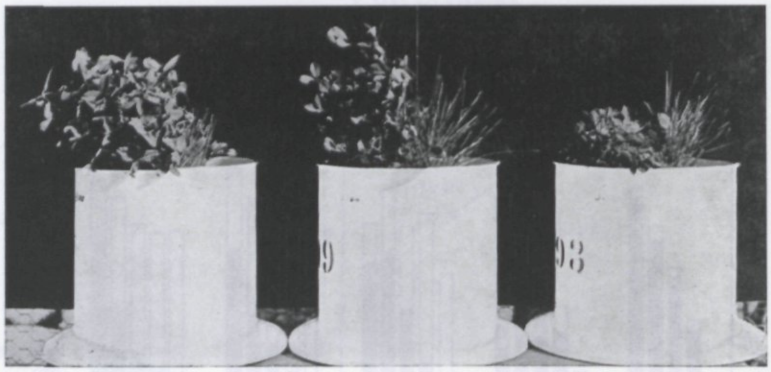
legume	Total nitrogen in grass in mg N per pot		
	until the first cut of the legume on 10 Sept.	until the second cut of the legume on 2 Dec.	until 7 March after killing the legume on 2 Dec.
red clover	44.7 ± 1.3	31.1 ± 2.4	294.1 ± 26.3
white clover	56.8 ± 4.7	64.2 ± 5.8	137.3 ± 13.6
lucerne	67.4 ± 5.0	43.7 ± 6.1	307.9 ± 21.3
control*)	23.9 ± 0.8	11.6 ± 0.7	37.2 ± 3.0

*) In the control pots the root systems of the legume and the grass were separated by a sheet of glass.

The table shows that in the first period of growth up until 10 September all the legumes contributed a definite, though small, amount of nitrogen to the grass. It was noticeable that the nitrogen contribution from lucerne and white clover was considerably greater than that from red clover. In the second period of growth from 10 September to 2 December the nitrogen contribution from white clover was greatest and that from red clover again the least, as can be seen in plate 9.

After the leguminous root systems had been killed on 2 December, large quantities of nitrogen became available to the grass.

Plate 9. The effect of red clover (left), lucerne (centre) and white clover (right) on grass growth with mixed root systems. The photograph was taken after the first cut of the legumes.



The nitrogen contribution during active growth of the legumes, although clearly demonstrable, was relatively slight. Whether this effect resulted from excretion of nitrogenous compounds by the root system or from the decay of roots cannot be ascertained from this trial. The trial does seem to show, though, that in practice the really important nitrogen effects of clover are predominantly associated with the release of nitrogen which occurs during the breakdown of roots and other plant residues.

Clover in an agricultural system

In countries such as Australia and New Zealand, which are almost entirely dependent on legumes for supplying their nitrogen requirements, extensive studies have been conducted into the effect on the grass/clover balance of nitrogen released during the breakdown of soil organic matter.

The Australian investigator DONALD [7] points out that on poor soils, provided that the supply of water and minerals is adequate, clover is completely dominant in the young grassland and is able to fix hundreds of kilograms of nitrogen per hectare. Much of this nitrogen is returned to the soil in the form of leaf and root residues and in the dung and urine of the grazing animal, and the level of soil nitrogen gradually rises. There is a resultant increase in the mineralization of nitrogen from this relatively nitrogen-rich material and grasses then have the opportunity to develop and to make up a larger share of the sward. What change there will be in the percentage of clover in this nitrogen-rich sward depends to some extent on how aggressive the grasses are and on how the grassland is managed. Although a relatively high percentage of clover is maintained by the right type of management one might easily suppose that as a result of the high levels of nitrogen in the sod the clover would absorb relatively more mineral nitrogen and fix less nitrogen from the atmosphere. This would therefore lead to the conclusion, in accordance with Donald, that a relatively decreasing rate of nitrogen ficsation, rather than a constant one, should be ascribed to the clover in an ageing sward.

Under New Zealand conditions SEARS [14] describes how a grass-dominant phase is attained after initial clover dominance in the manner described above; at this stage use may be made of the high level of soil fertility by ploughing and sowing to arable crops. After a gradual decrease in the level of soil fertility has taken place, a clover-rich mixture may be sown again and the cycle can start afresh.

It will be clear from the above that even if no fertilizer nitrogen is used, nitrogen can still have a key position in the creation of a given grass/clover ratio in the sward, at least if sufficient water and other nutrients are supplied.

However important nitrogen may be in determining the ratio between clover and grass, we do not intend to create the impression that the last word has been said on the topic of grass/clover competition. The amount of clover in grassland is also affected to a considerable extent by the nature of the competing grasses; perennial ryegrass and cocksfoot, for instance, are more aggressive than meadow fescue and timothy. Managing the grassland in such a way that the herbage is kept short can result in good clover persistence even at high rates of nitrogen. Furthermore, it is still completely unclear why it should be that on some soils the clover completely disappears from the sward after a year or two and yet on others it becomes quite a strong dominant. In the Netherlands fen soils support practically no clover; on many sandy soils too the clover is hardly able to persist, and this may be to some extent associated with too low a pH. On the other hand clover grows vigorously on loess and in the IJsselmeerpol-

ders. It might perhaps be that the best clover growth is to be expected on moisture-retaining but well drained clay or loamy soils where the pH is not too low.
Lastly it is possible that poor growth of clover may in a number of instances be associated with parasitic infection (the occurrence of 'ineffective' strains or of bacteriophages which digest the nodule bacteria), while recently eelworm infection has been indicted as a likely cause of reduced clover vitality.

To sum up, the following may be said about the nitrogen response of a mixture of clover and grass.
In a mixed sward nitrogen is absorbed preferentially by the grass and the growth of the grass component is strongly stimulated. The remainder of the applied (available) nitrogen, which is absorbed by the clover, has no initial effect at all on the growth of this crop since uptake of mineral nitrogen is matched by a simultaneous reduction in fixation of atmospheric nitrogen. The strong stimulation of grass growth leads to shading and suppression of the clover unless the latter grows up with the grass as, for instance, red, ladino and some varieties of medium white clover do. Clovery swards respond poorly to applied nitrogen, since up to a certain point the nitrogen results in replacement of the clover by grass; beyond this point dry-matter production increases as the amount of nitrogen applied is increased further.
The clover itself makes a considerable contribution towards enrichment of the sod with nitrogen, resulting in better opportunities for the grass and finally the suppression of the clover by the grass, a phenomenon which is well known in Australia and New Zealand.
From the results of these and other experiments both WALKER [17] and LINEHAN [11] have come to the conclusion that in grassland farming it is sensible to make a conscious distinction between plots where the supply of nitrogen is left to the clover and plots which are geared to fertilizer nitrogen. Some factors which play a part in the choice between the two systems are further discussed below.

Clover nitrogen or fertilizer nitrogen?

From the foregoing the point unavoidably rises as to whether preference should be given to clover or to fertilizer as a source of nitrogen for grassland.
The British investigator ELLISON [8] notes that while agriculturalists and other experts are still divided about the answer to this question, the farmers have solved the problem in accordance with their own judgment and to suit the local conditions. In this way the New Zealand farmers are allowing white clover to provide for the entire nitrogen needs of their grasslands and they ensure that adequate amounts of phosphate are applied to their pastures. Because of the favourable climate the clovers are able to grow and fix nitrogen over a much longer period than they can here, while the grasses are able to protect any nitrogen that is released from being leached out. According to ELLISON it is also necessary to point out that the management system used in New Zealand is a relatively extensive one, with low farm costs, in which the accent falls on production per man. ELLISON contrasts this with the situation in the Netherlands, where the climate is much less favourable for the growth of clover and where in addition the high population density and the intensive use of the land compel the use of intensive patterns of management. Under these conditions fertilizer nitrogen is almost exclusively used, as a means of achieving a high output per unit area.
According to ELLISON it is clear that the factors which have led to the differences in farming systems and in the role which legumes play in them are economic far more than agricultural.
Under extremely favourable conditions in New Zealand (WALKER [19]) clover may fix up to 600 kg N per ha per year and DM yields of up to 14000 kg per ha may be achieved without the use of fertilizer nitrogen. SEARS [13] states that, not counting nitrogen from dung and urine, the grass has a good 100 kg N available to it by way of underground transfer from the clover. It is clear that under these conditions clover functions as a cheap and efficient source of nitrogen.
DAVIES and WILLIAMS (cited by GREEN and COWLING [9]), working in England, come to the conclusion that clovery grassland, under British conditions and without the use of fertilizer nitrogen, produces a long-term average of about 5000-6000 kg dry matter per year, whereas with nitrogen yields of 10000 kg dry matter per ha are readily achieved. DAVIES [4] also states that in grassland farming the choice of clover or artificial fertilizer as a source of N is determined far more by economic than by agricultural motives. On larger farms it may be an attractive proposition to manage the grass/clover stand in such a way that the most profitable use is made of the clover as a source of nitrogen. On small farms, however, the output of a grass/clover sward without nitrogen will not be adequate to satisfy the heavy demands of intensive farm management, and fertilizer nitrogen will have to be applied in order to raise the level of herbage production.
We have heard above what has been said by several investigators overseas, where a possible choice

between clover or artificial fertilizer is motivated mainly on economic grounds. Alongside this, however, we need to make the point that the possibility of making a choice does not always exist. In the Netherlands the conditions for clover growth, especially those bound up with soil type, are less favourable than in some of the surrounding countries, mainly because of the high percentage of sandy soils of relatively low pH. As a result fertilizer nitrogen has to be resorted to in order to achieve high yields of herbage.

Where conditions are favourable for the growth of clover, it needs to be borne in mind that clover starts its spring growth later than grass does and reaches its maximum output in mid-summer after grass growth has passed its peak. According to WALKER [17], LINEHAN [11] and DAVIES [4] this disadvantage of a late start to spring growth can be overcome by applying fertilizer nitrogen in early spring; if care is taken that the herbage does not become too tall then suppression of the clover can be avoided, summer herbage production can be left to the clover and more fertilizer nitrogen can be applied in the autumn. The growing season can be lengthened in this way and full use can still be made of the clover. We have seen this system successfully applied on an alternate husbandry experimental farm operated by the Kali-Importmij (Potash Import Co.) in collaboration with the Dutch national agricultural advisory service. On this farm, which is situated on loess soil near Limbricht, clover is the mainspring of the enterprise and fertilizer nitrogen is applied in spring and autumn to even out the herbage production. In 1960 the system resulted in efficient use of clover at a nitrogen input of 130 kg N per ha per year. It was also apparent that on the loess soil the clover content may decline quite considerably under the effect of heavy dressings of nitrogen, but the clover does not disappear from the stand.

On dry sandy soils, however, on which alternate husbandry is practised because permanent pasture does not remain productive, the percentage of clover usually drops steeply within a few years after sowing. The growth of clover on these soils is much less vigorous than, for instance, on loess and its output of dry matter is too limited for it to be used as the basis for a production scheme. It is more sensible on these soils to encourage the growth of grass by applying nitrogen, and to regard the growth of clover solely as an extra. Even though the clover may not serve as a cheap source of nitrogen any more, a certain amount of clover among the grass is still an attraction in view of the favourable effect it has on the mineral composition of the pasture herbage, particularly as concerns Mg and Ca. Even if there is little or no clover left in the stand it is still possible to farm the grassland intensively without creating any difficulties for the livestock. Experiences on the nitrogen experimental farms have shown that at very high inputs of nitrogen, judicious manurial practices taking into account the fertility status of the soil, the mineral content of the herbage and the mineral balance of the farm can prevent dreaded ailments of intensive farming such as grass tetany and give extremely good financial returns.

There are of course other, occasionally fortuitous, circumstances which have contributed towards stimulating the development of grassland farming along certain lines. New Zealand has no coal-mining or petroleum industry and therefore has no hydrogen, the important raw material for founding an industry to manufacture combined nitrogen.

In the Netherlands just after the war, when lack of foreign exchange severely impeded the importation of concentrates, fodder production on the farm received a strong impetus, with Government encouragement, and this has led to a considerable increase in the use of nitrogen.

In Denmark, where farms are larger and the soil has a higher pH, conditions are more favourable for the cultivation of clover, though the use of nitrogen is increasing quite considerably in that country.

To sum up we can associate ourselves with the conclusions of ELLISON [8] and DAVIES [4], that applying fertilizer nitrogen or making use of clover is determined to an important extent by economic motives. On larger farms such as occur quite frequently abroad, where it is possible to achieve a high return on labour at a fairly low output per hectare, it can be an attractive proposition to use clover as a cheap source of nitrogen. In the Netherlands, with its numerous small farms, a high output per hectare is essential to maintain a high return on labour. Moreover, there are many places where clover will not grow vigorously enough to form the basis of a production system. Where conditions are favourable for clover, such as on the loess, then clover can occupy a pivotal position and fertilizer N can be applied in early spring and in late summer to compensate for any lack of growth at these times.

A farming system based on growth of clover shows up to its best advantage in an alternate husbandry system, but this requires a certain amount of skill on the part of the farmer, since establishing clover in a cover crop is not a feat that everyone can make a success of.

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