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Dependence of available nitrogen on the distribution of rainfall

Summary

It depends on the intensity of rainfall which part of the soluble nitrogen will be leached down in winter. Nitrogen bound in organic form and mineralized not yet or nitrogen already taken up by the crop, e.g. grass, remains in the soil and will be available to the next crop.
In the warmer seasons nitrogen may be leached down only occasionally. Differences in rainfall in this period may be responsible for the amount of mineralizable nitrogen built up and becoming available in the next year. Large amounts of nitrogen (in both forms) accumulate especially in a dry season. Such nitrogen carried over from the preceding year, may contribute appreciably to the nutrition of the next crop, especially when the latter is sub-optimally dressed.
The fluctuations of nitrogen uptake by crops on arable land and grassland and on different soils are rather similar. In general they seem to reflect the pattern of rainfall distribution.

During the autumn a stock of nitrate is usually built up in the still rather warm soil. This nitrogen is very liable to leaching by rain, in contrast to the nitrogen still bound in organic form. Yet, if the rainfall in the winter is low, not all mobile nitrogen will be leached, a part of it being saved for the next crop, and the yields may be strongly influenced by this residual nitrogen.
It was possible on a field trial to explain for 87% the variance of the yield of rye grown without nitrogen dressing during 20 years in a rotation potato-rye-oats on a humic sandy soil by the differences in the total rainfall for the October-February period. This effect is smaller for dressed crops. However, with normal dressing (75 kg/ha N) still 33% of the variance could be explained. The variance of rye yields in practical farming could be explained for 23% [1].
The conclusion drawn from the above comparison of different years could be confirmed by intentionally varying the intensity of rainfall in winter. This was realized by occasionally intercepting the rain by means of a glass cover [2]. Grades of nitrogen dressing applied on the formerly covered and the not covered plots have shown that even relatively small differences in winter rainfall resulted in appreciable differences in nitrogen response of the crop. For instance, a decrease of rainfall from 224 mm to 162 mm proved equivalent with the effect of 34 kg/ha of nitrogen.
In the warmer seasons the risk that nitrogen would be leached beyond the reach of the roots is much smaller. However, in the extremely wet spring of the year 1965 appreciable amounts of nitrogen were lost in permeable soils and additional dressing became necessary.
The mineralization of nitrogen might be enhanced in a wet soil, and excessive rainfall will leach soluble nitrogen. Thus, under these conditions the content of

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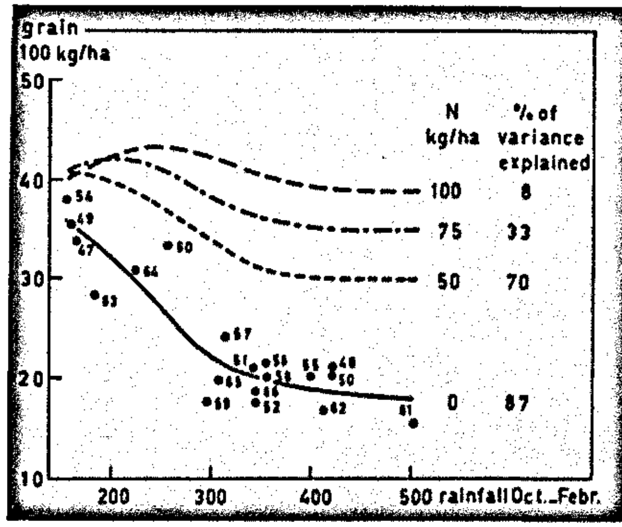
Fig. 1. Effect of the total rainfall over the period October-February on the yield of rye grown at different levels of nitrogen nutrition on an experimental plot.



nitrogen present in the soil in a mineralizable form can be decreased.

The importance of these losses was demonstrated by an experiment with artificially varied amounts of rainfall performed in the spring of 1965 during the period March-July. Not only interception of natural rainfall, but also additional precipitation by sprinkling was applied. The small strips (25 m^2) with different rainfall were then used for varied nitrogen dressing and were seeded to turnips in August.

Beforehand, the amounts of soluble nitrogen were determined in the upper 50 cm of the soil. In the plots provided with 204 mm of rain 77 kg/ha of nitrogen were found, whereas with 537 mm of rain only 29 kg could be detected. Thus, the difference proved 48 kg/ha of soluble nitrogen in the top 50 cm. The sub-soil below 50 cm in this experiment was pure sand. Roots did not penetrate into it and it certainly did not contribute any appreciable amount of nitrogen. The amounts of nitrogen supplied have been plotted against the uptake by plants (Fig. 2).

The different intensity of rainfall in the preceding period proved markedly to influence the uptake of nitrogen. From the curves it can be read that the effect of a difference in the amount of rainfall between the plots with the lowest and with the highest rainfall equals to the effect of a dressing with 72 kg/ha of nitrogen, whereas the contents of soluble nitrogen at the moment of sowing the turnips differed in these plots only by 48 kg/ha, as has been mentioned. With medium rainfall an intermediate effect has been found. The result is an indication that during the growth of the turnips the mineralization of nitrogen was higher on the formerly dry than on the formerly wet plots.

It seems probable that the same may occur under normal conditions in autumn. Is the weather dry in that period, then soluble nitrogen may accumulate in the soil, but besides that the content of mineralizable nitrogen may also remain higher than in a wet period. This was confirmed by a similar experiment started in the summer of 1963.

Four strips of soil were dressed with 20 tons per ha of stable manure on August 23 and the amounts of rain were varied from this date onward till March 25,

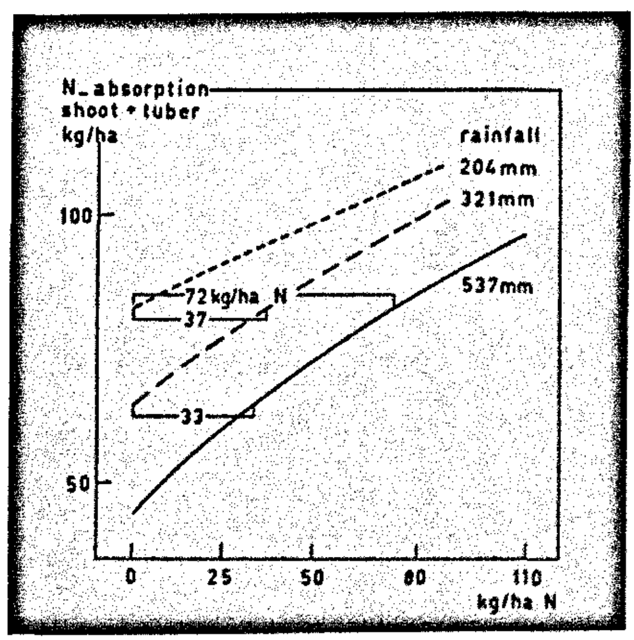
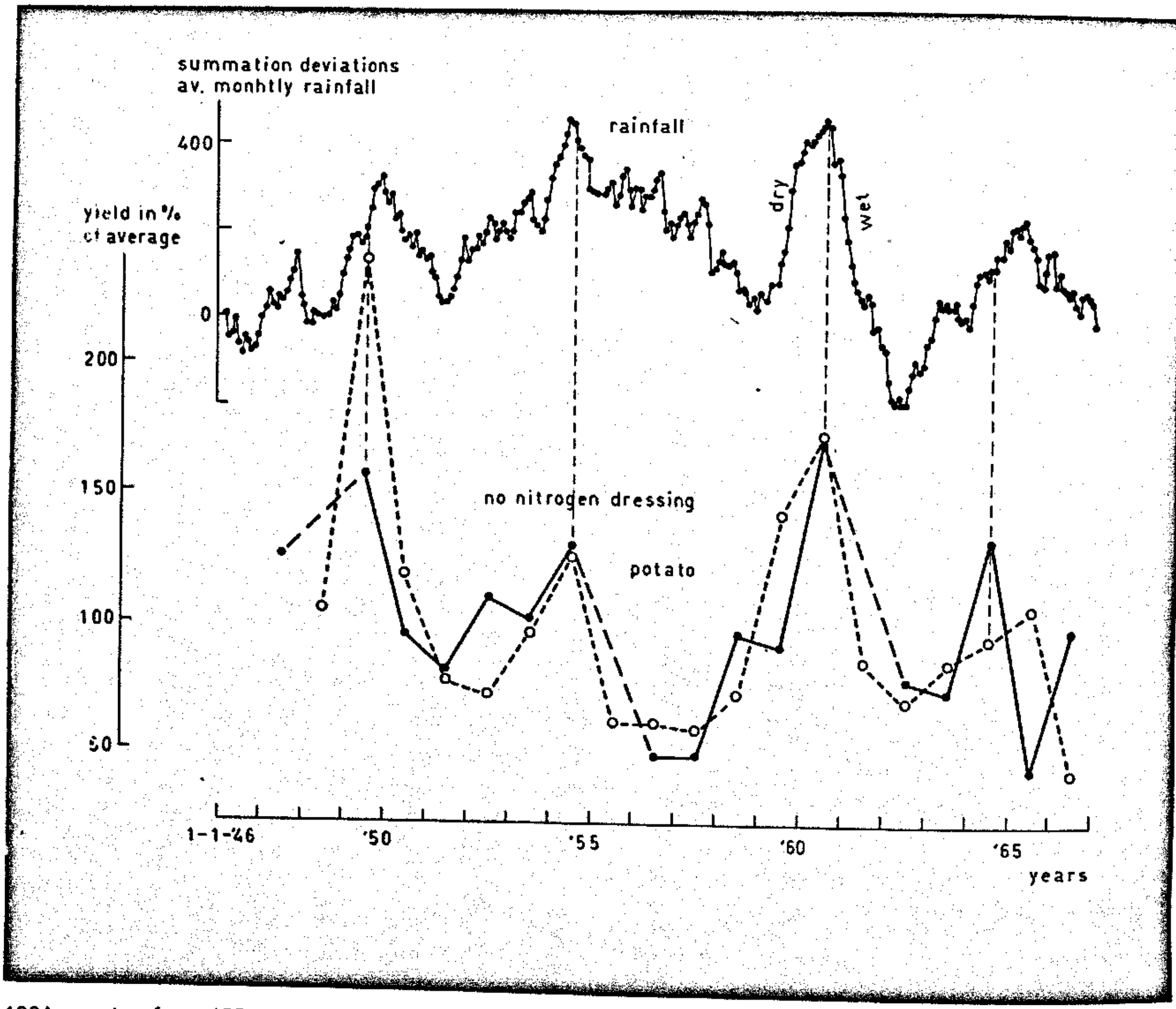


Fig. 2. Relation between nitrogen dressing and nitrogen uptake by turnips grown on plots with different amounts of rain during preceding March-July. The saving effect of low rainfall on the available nitrogen can be deduced from the curves (extreme 72 kg N/ha).



1964, varying from 185 to 407 mm over the 7 months. Then potatoes were grown and dressed with different amounts of nitrogen. Already in the first half of June differences in the development of the crop became apparent, due to the level of nitrogen dressing. In the beginning there appeared no differences between the strips, but at the end of June such differences became clearly visible. They appeared purely as nitrogen effects, and no doubt must be mainly ascribed to mineralized nitrogen gradually becoming available to the crop.

The tubers harvested on the strip with the least rain in the preceding autumn and winter proved to have taken up 29 kg/ha of nitrogen in excess of those harvested on the plots with the same nitrogenous fertilization but with the highest amount of rain. According to general experience about 50% of the fertilizer-nitrogen can be found back in the tubers so that this difference in the tubers may have accounted for a mineralization of nitrogen in the soil of at least 50-60 kg/ha higher in the formerly driest than in the formerly wettest plots.

Now the yields of crops grown on long-term experimental plots will be considered. It has often been found that the yields decrease during a period of successive wet years and rise in drier periods [3, 4]. This phenomenon is most spectacular when yields of crops grown without nitrogen dressing are considered. The yields of one of our long-term experimental fields are taken as an example. The soil of this field is rather permeable so normally no appreciable amounts of soluble nitrogen are retained, even in relatively dry winters.

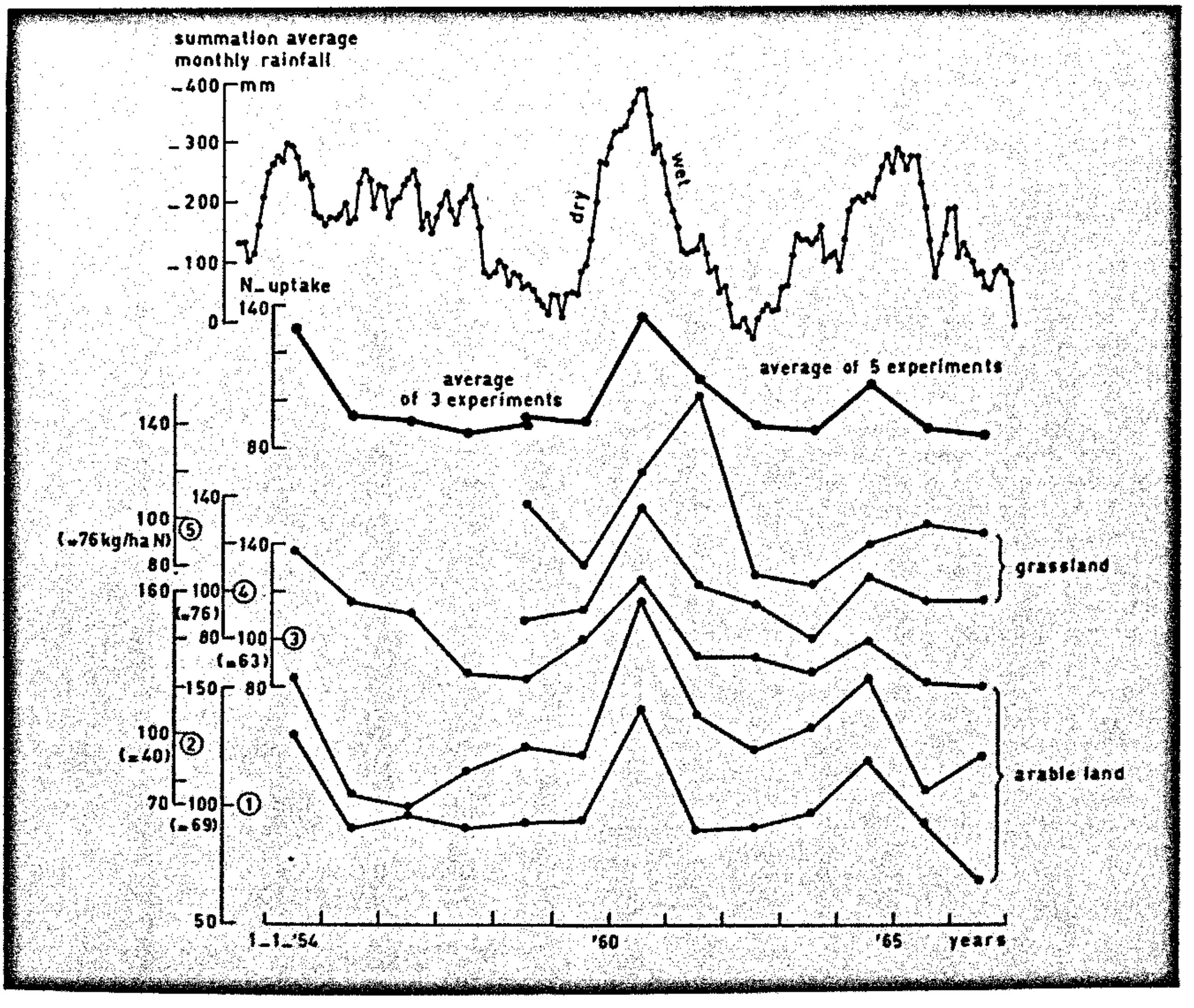
It may therefore be assumed that a crop grown without nitrogen dressing mainly depends on the nitrogen,

Fig. 3. Yields of rye and potatoes grown simultaneously on the same experimental plot without a nitrogen dressing (oats grown since 1954 omitted), compared to the distribution of rainfall as indicated by a summation curve of the deviations from the monthly averages. The yields of the crops expressed in percentages of the average yields of the whole period.

Fig. 4. Average uptake of nitrogen by three arable crops and by grass (1st cut) grown at low nitrogen level on different soils in the northeast of The Netherlands, compared to the pattern of rainfall.
1. Old reclaimed moor soil. 2. Recently reclaimed moor soil (same as in Fig. 3). 3. Light clay soil. 4. Heavy clay soil. 5. Peat soil.

produced by mineralization of organic matter. This amount on this soil is rather small and the crops grow up deficient in nitrogen. Consequently the mineralizable nitrogen is here a strictly limiting growth factor. It might be suggested that under these conditions the effect of this factor on the yields of crops grown without nitrogen dressing is at least as important as that of prevailing atmospheric conditions during the growth.

This supposition seems to be confirmed by the fact that the ups and downs of the yields of potatoes, rye and oats growing in the same year (belonging to the same rotation) are generally paralleling each other. This could hardly be expected, if the direct effects of meteorological conditions would have a dominating influence. As a matter of fact the growing seasons of winter rye and late potatoes are scarcely overlapping one another. Thus, it seems likely that it is mainly



the amount of mineralizable nitrogen which has been responsible for the corresponding fluctuations of the yields of the three crops.

An elucidation of the above assumption is given in Fig. 3. The rainfall curve of this figure is a reversed summation of the deviations from the average rainfall for each month of the year. A rise of the curve represents a drier period than normal and a fall a relatively wet period.

The fluctuations of the crop yields are clearly following those of the reversed rainfall. Apparently the yields rose during dry periods, and fell in the wetter ones.

Not only the yields, but also the uptake of nitrogen — consequently the availability of nitrogen — proved to be negatively correlated with the deviations of the rainfall.

The most precise picture of the fluctuations of nitrogen uptake might be obtained by averaging the uptake of the three crops grown in the same year. Hereby, the averages of the plots without nitrogen dressing and of those with moderate dressing have been calculated.

The nitrogen uptake of five experimental fields on different soils in the vicinity of Groningen have been compared. Two of these fields were grassland. Here only the first cut has been considered. It was always mown at the moment when about 4500 kg of dry matter/ha was estimated to be available on the plot with the highest nitrogen dressing (150 kg N/ha).

Thus, the yields were rather equal in all years, but the nitrogen content of the grass, and consequently the nitrogen uptake, fluctuated. The averages of the nitrogen taken up without and with low nitrogen dressings (30 and 60 kg N/ha respectively) have been calculated and expressed for each field separately as percentages of the average over the whole period. Finally the corresponding averages for all fields have been calculated (Fig. 4). The summation curve of the deviations from the average monthly rainfall at Groningen is also shown in this figure.

The pattern of nitrogen uptake is remarkably similar for all fields. It seems that the kind of soil is not important therefore. Even grassland is not essentially different from arable land.

Though the series of observations is still rather small and more data are needed, it seems admissible to claim that the amounts of available nitrogen reflected the rainfall pattern.

Since 1954, during a rather wet period, the nitrogen uptake decreased on the whole. A high peak appeared in 1960 following the preceding dry year. In the next period, which again was wet, the uptake decreased again. A new rise was apparent in the drier years 1963 and 1964, followed again by a fall in the last wet years.

As a general conclusion it might be stated that soluble or mineralizable nitrogen accumulates in dry years and then is responsible for a peak in the following year. On arable land, where the soluble nitrogen is liable to leaching, the latter will occur when the winter is wet. In grassland the pattern might be different as the soluble nitrogen here will mainly be taken up by the grass even in late autumn, saving it from leaching.

We consequently may conclude that the amount of soluble and mineralizable organic nitrogen carried over from one year to the next one is controlled by the meteorological conditions.

This varying supply of nitrogen promotes a higher variability of crop yields over years. It will belong to a sound fertilizing policy that the fluctuations of this soil-growth factor are taken into account.

(1) PAAUW, F. VAN DER. Anpassung der Düngung an die *Witterungsverhältnisse. Verhandl. Intern. Bodenk. Ges.* 1958 (II), 78-82 (1958).

(2) PAAUW, F. VAN DER. Effect of winter rainfall on the amount of nitrogen available to crops. *Plant Soil* 16, 361-380 (1962).

(3) PAAUW, F. VAN DER. Periodic fluctuations of soil fertility, crop yields, and of responses to fertilization effected by alternating periods of low or high rainfall. *Plant Soil* 17, 155-182 (1962).

(4) PAAUW, F. VAN DER. Wetterabhängigkeit der Bodenfruchtbarkeit. *Z. Pflanzenernähr., Düng., Bodenk.* 108, 129-137 (1965).