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ROLE OF THE ORGANIC CYCLE IN FLUCTUATIONS OF CROP YIELD

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SUMMARY

To explain why both soil-fertility factors and crop yields vary gradually, following undulating curves, it is postulated that changes in the dynamic equilibrium existing between synthesis and breakdown of soil organic matter are to a large extent responsible.

It is assumed that the amount of nitrogen available to plants is a measure of conversions of the organic matter, provided that some conditions are fulfilled. The amounts of available nitrogen in different soils fluctuate rather similarly to the distribution of rainfall over longer periods.

Fluctuations of crop yields are intensified by organic manuring and are most pronounced on fertile soils. On soils with weak nitrogen mineralization the fluctuations are negligible.

INTRODUCTION

The current conception that the variability of crop yields is due to the variation of meteorological conditions prevailing *during* the growth of the plant gives too simple an interpretation. Meteorological conditions in a long period preceding the growing season are also important. The reason therefore is that soil fertility is cumulatively affected by weather conditions in this period. As the effect of these changes in the soil on plant growth is considerable, a large part of annual yield fluctuations has to be attributed to this factor. The following arguments support this conception.

1. In a variable climate a random variation of crop yields might be expected. However, this variation proved clearly not to be random. Yields in consecutive years follow an undulating curve (van der Paauw 1962a, Figs. 7–11, 1965a, Fig. 7, 1966, Fig. 5).

2. The responses of growing crops during different parts of the growing season are similar in many respects. If the crop yields were actually controlled by the atmospheric conditions, a less close agreement might have been expected. It consequently seems probable that the same factor controls the yields of all crops in the same year.

3. Various soil factors, such as pH, content of water-soluble phosphorus and content of exchangeable potassium behave in the same way as crop yields. Apparently soil fertility changes continually.

4. The changes of these soil factors parallel the fluctuations in the distribution of rainfall over longer periods. It is suggested that the changes of soil fertility factors are caused by the cumulative effects of meteorological fluctuations.

5. It was found that crop responses to dressing with fertilizers corresponded to the fluctuations of soil factors. A fall in the content of water-soluble phosphorus was associated with an increased response to this nutrient, and vice versa. This affords strong evidence that changes occurring in the soil are responsible for the fluctuations of crop yields (van der Paauw 1962b, Fig. 15; 1965, Fig. 3; 1966, Fig. 4).

6. The nitrate content of the soil is a rapidly varying soil factor. The amount of soluble nitrogen present in the spring depends on the intensity of rainfall in the preceding winter (van der Paauw 1962a, Figs. 1–3, 1965, Fig. 4, 1966, Fig. 1). The variance of yields of rye grown without nitrogen dressing can for 87% be explained by the differences in the sum of rainfall in the period October-February.

We may conclude that an important intermediary function between preceding weather conditions and crop yields is performed by the soil. It must be considered a serious omission that this function of the soil has been overlooked in agro-meteorological studies. It has led to an overestimation of the direct effects of atmospheric factors on plant growth and crop yields.

DISCUSSION OF CAUSATIVE FACTORS

Which soil factors are especially responsible for the intermediary function of the soil in weather—crop-yield relationships? Increased fertilization in recent times, especially with nitrogen and phosphorus, has mitigated the significance of variations in the availability of nutritional soil factors as a cause of yield fluctuations. Nevertheless, their influence is still considerable. In the field trial already mentioned with rye normally dressed with nitrogen 33% of the variance of yields can still be explained by differences in the amount of available nitrogen due to the variation of winter rainfall.

The coincidence of fluctuations in the actual structure of the soil with the intensity of rainfall may also be mentioned. Unfavourable effects may be worsened by human interference. Soil structure is improved by periods of heavy frost and intensive drought. No doubt, soil structure may be considered one of the most important factors affecting soil productivity in the long run.

However, I want to suggest another explanation, more general in nature. It is common experience that the conversion of organic matter has far-reaching consequences for soil fertility. And now arises the question in how far the dynamic equilibrium between synthesis and breakdown of organic matter is also susceptible to changes of the rainfall pattern. A shift in this equilibrium due to changes in the level of aerobiosis of the soil might also control the mobility of plant nutrients and soil structure.

We may assume that the disintegration of soil organic matter is paralleled by changes in the amounts of mineralized nitrogen. This thesis may be especially valid when the whole growing season and one single soil are under consideration, and when the same crops are grown continuously on the soil. In our field trials potatoes, oats, and rye or wheat are grown in rotation, all, however, being represented each year.

On one of these fields the soil is rather permeable. Most of the soluble nitrogen is lost by leaching even in dry winters. Here, plants grown without nitrogen dressing are mainly supplied by nitrogen mineralized during the growing season. Since nitrogen is the main factor limiting plant growth on this field, the amounts of *mineralized* nitrogen are reflected by the crop yields, when not dressed with nitrogen. Yield fluctuations appear to parallel the rainfall pattern (Fig. 1). Potatoes, rye and oats behaved in a similar way, indicating that one soil factor, nitrogen, has controlled crop growth in all cases. As the growing seasons of winter rye and of a late variety of potatoes only partly overlap one another, a different result might have been expected if the yields had been mainly controlled by prevailing atmospheric factors.

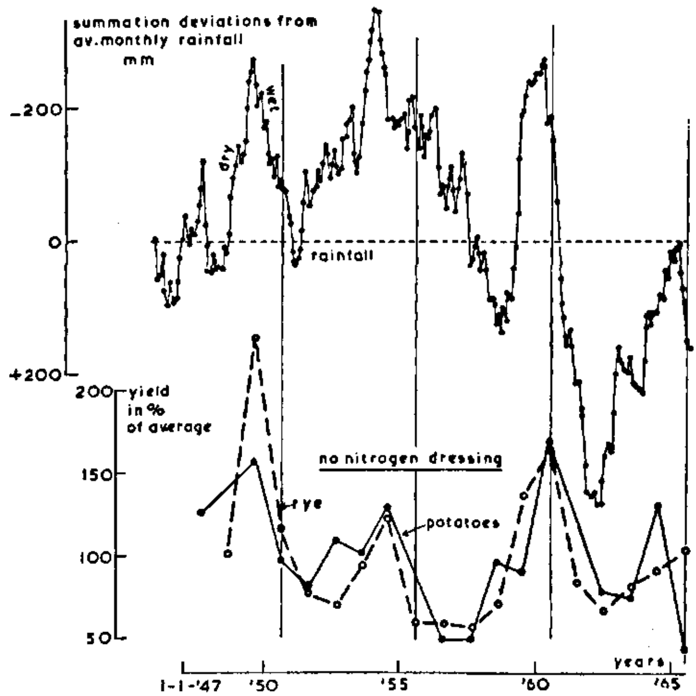

Fig. 1. Yields of potatoes and rye (oats being omitted) grown without nitrogen (expressed as percentages of the average yield over the whole period), compared with distribution of rainfall. The latter is represented by a summation curve of the deviations from the average rainfall of each month separately. Rising parts of the curve indicate dry, falling parts wet, periods.

The average of the amounts of nitrogen absorbed by the crops grown at a low level of nitrogen-dressing on these field trials may also afford a reliable measure of the intensities of the overall mineralization during the growing season.

Comparing fluctuations of average nitrogen uptake on different soils, spread over the Netherlands, a remarkable agreement has been found, though the distribution of rainfall was not quite the same in all places (Fig. 2). The thick line represents the average course of nitrogen uptake on five field trials on arable land. The uptake was high in 1954 after a relatively dry period. It fell off gradually in the following wet years. A high peak appeared again in 1960 after the preceding very dry period. This was followed by a new fall in the next wet years, again alternated by a rather low peak in 1964. Apparently the amounts of available nitrogen have rather closely followed the pattern of rainfall.

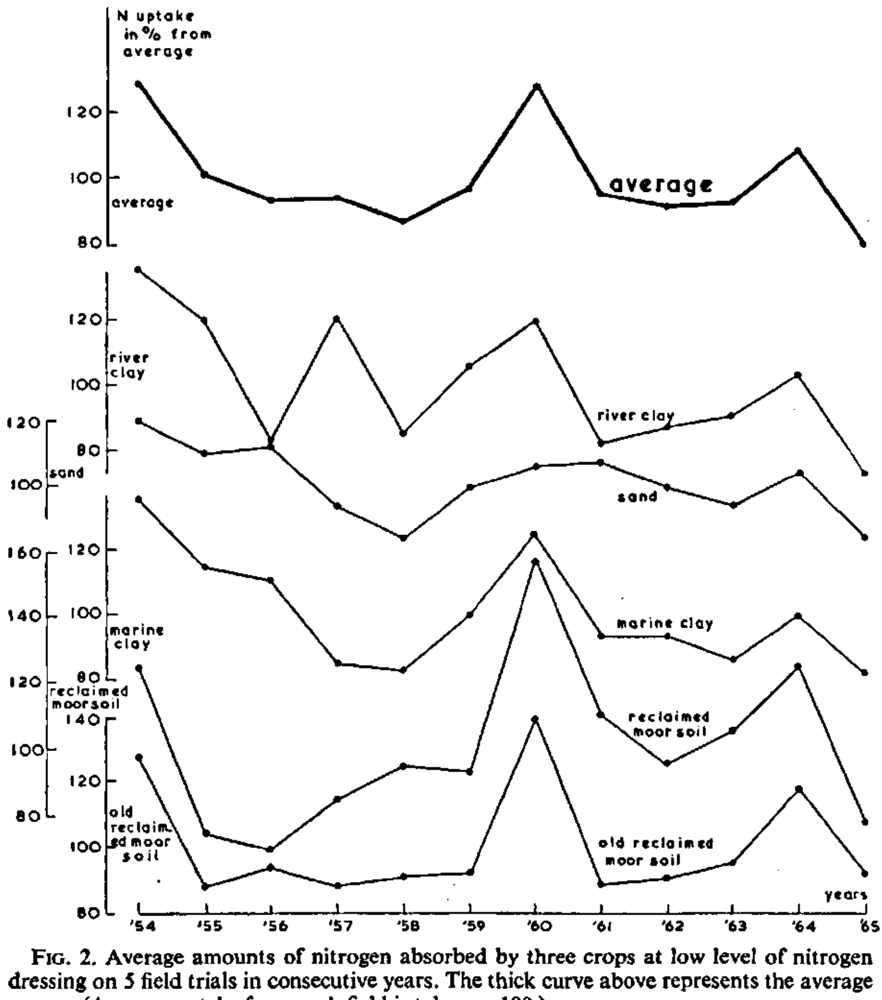

FIG. 2. Average amounts of nitrogen absorbed by three crops at low level of nitrogen dressing on 5 field trials in consecutive years. The thick curve above represents the average course. (Average uptake from each field is taken as 100.)

It might be suggested that the intensity of the fluctuations will be the stronger the higher the content of mineralizable substances of the soil. This has been verified by the results of a field trial conducted in a Zuider Zee polder (Wieringermeer; compiled by Mr. L. C. N. de la Lande Cremer) applying various systems of organic manuring (stable manure, town-refuse compost, straw, green manure). The distribution of rainfall was not quite the same on all fields and the average yield increases caused by organic manuring have been obtained with different crops. Nevertheless, organic matter added to the soil obviously behaves similarly to native soil humus, and yield fluctuations are intensified by organic manuring (Fig. 3).

The most pronounced yield fluctuations are observed on young marine-clay deposits of high fertility. On newly reclaimed high-moor soils, on the contrary, no appreciable yield fluctuations could be found in spite of their

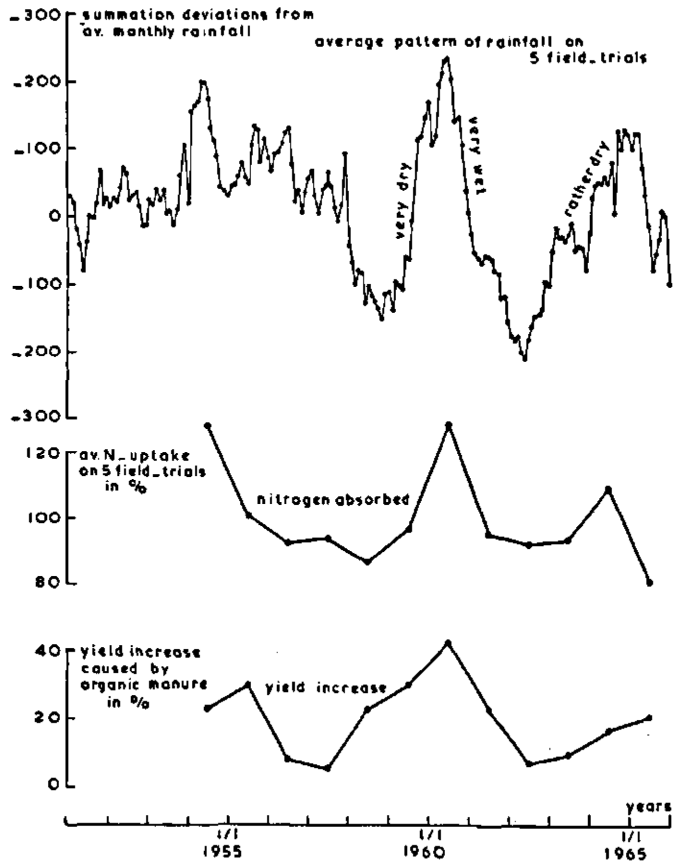

FIG. 3. Average absorption of nitrogen by crops grown at low level of nitrogen dressing on 5 field trials spread over the Netherlands (from Fig. 2), and yield increases in percentages due to organic manuring on another field trial. Both curves reflect the distribution of rainfall represented by the summation curve.

high content of organic matter. But the peaty substances in these soils are very resistant and mineralization of nitrogen very slow. This contradictory result on fertile and infertile soils also emphasizes that the driving force of yield fluctuations is to be sought in the changes in the cycle of the soil organic matter brought about by the fluctuations of rainfall distribution.

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