The omission of the aspects of soil fertility in relationships of weather to crop yield

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Recently Monteith (1966) has formulated the "philosophy" of agricultural meteorology, citing Herodotus' *Annuus fructum fert, non tellus.* In free translation, "the yield of a crop is determined by prevailing weather conditions rather than by the state of the soil".

My objective is to show that Herodotus was right in his country, but that his "philosophy" may be wrong in Britain and other countries bordering the North Sea. The reason why is that Greece has a warm and dry climate, but here relatively dry years alternate with years marked by excessive rainfall. In a dry country water is always the growth controlling factor. Excessive rainfall, however, gives rise to a deterioration of the fertility of the soil. This may be worsened by soil management by man. On the other hand dry weather favours a restoration of soil fertility. These effects are cumulative, each next wet year in succession being worse in its effect than the preceding. An alternation of series of consecutive wet or dry years can give rise to wave-like fluctuations of soil fertility. This part played by the soil between weather conditions and crop yields appears to have often been overlooked by agrometeorologists. The aim has been to explain the differences of crop yields through the variations in atmospheric conditions prevailing during the growth of the crop. This idea has presumably been accepted for lack of a plausible alternative.

Some factors are changed rather rapidly by the meteorological conditions. An example is the change in the supply of water soluble nitrogen caused by winter rainfall. As was found years ago in England by Russell among others considerable amounts of nitrates may be maintained in the soil after dry winters. They are lost by leaching in a rainy winter. These differences are then reflected by yield fluctuations when the level of nitrogen dressing is low. In a field trial, 81 per cent of the variance of the yields of rye, not dressed with nitrogen, could be explained by the variations in the total rainfall in the period November-February. This effect is reduced by dressing with nitrogen, but with 75 kg of nitrogen per hectare, which is normal in this region, 33 per cent of the variance can still be explained by this factor.

Changes of other soil factors may develop more slowly, as has been shown by a survey of the fluctuations of rainfall in the Netherlands during the last 86 years. Periods with rainfall considerably above the average alternated with dry periods, especially between 1920 and 1940.

On a long-term field trial the content of water-soluble phosphorus proved also closely to parallel the fluctuations of rainfall. In case of phosphorus deficiency the yield without phosphate dressing is controlled by the content of water-soluble phosphorus of the soil.

The yields obtained without phosphorus dressing, expressed in percentages of the yields with phosphorus, corresponded with the fluctuations of the content of water-soluble phosphorus. It seems admissible to claim a causal relationship. Another example is the content of exchangeable potassium which closely reflects the pattern of rainfall as indicated by a summation curve of difference from average.

The yields of crops grown without nitrogen dressing on a nitrogen deficient soil are a measure of the nitrogen supply by the soil. Apparently the formation of available nitrogen rises in consecutive dry years and falls in wet ones. High peaks may partly be explained by the protecting effect of preceding dry winters. It is especially important that rye, being a winter crop, behaves similarly to late varieties of potatoes. Their vegetation periods only partly coincide. This indicates that the fluctuations of the yields are mainly effected by the condition of the soil and not by the variations of atmospheric conditions.

In former times, when fertilization was low, the *fluctuations* of crop yields must have been *dominated* by the effects of fluctuating soil fertility. The same holds for *underdeveloped* regions in the present *time*.

Ample dressing with phosphorus and nitrogen has eliminated a considerable part of the variability, nevertheless, the fluctuations are still considerable. The yields in favourable years are often two or three times as high as those in unfavourable ones. Yields of different crops in practical farming on various soils are showing a rather similar picture, being more or less equal to the pattern of rainfall.

The average soil pH (in water solution), determined on long-term field trials on sandy soil, behaves similarly. It seems acceptable that pH is an index of changes occurring in the soil.

This dominating influence of soil fertility which appears in experiments as well as in practical farming is limited to the regions with climatic conditions similar to ours. These are characterized by an alternation of rather dry and wet periods. The fluctuations of soil fertility are reflected by plants ecologically adapted to these circumstances. Marginal crops in this area, such as maize, are supposed to be more affected by the direct effects of atmospheric factors, the same holds true for crops normally harvested in a vegetative state. It may be expected that in continental climates plants are more sensitive to weather conditions prevailing during the vegetation period. This is the reason why Herodotus was right.

Though nutritional factors may still be causative in respect to yield differences directly effected by weather, it is certain that an important part is also brought about by soil physical factors. Moreover, the considerable fluctuations of the amount of available soil nitrogen may indicate also that the cycle of soil organic matter is involved in the processes operated by meteorological variations.

In the opinion of the author the significance of *atmospheric* factors directly affecting plant *growth* is often overestimated. Of course, it will not be denied that *limiting* growth factors may control crop *yields*. But so long as these factors are not extreme (frost, hail, storm, excessive rainfall, drought), it seems unlikely that they would explain average yield differences of 100 per cent and more. In the extremely bad year 1965 no appreciable yield depression occurred, provided that the status of the soil was not damaged.

The adaptability of the plant on the other hand is underestimated. Temporary limitations of growth due to unfavourable weather conditions are often counterbalanced by accelerated growth in a following period. Time is lacking to give further examples.

The new conception of the relation of weather to crop yield allows us to forecast the need of fertilizers and the crop yields. In the Netherlands increases or decreases of intended nitrogen dressing are advised in February in order to eliminate differences in available soil nitrogen. This prediction is based on knowledge about the relation between rainfall during the preceding winter and crop response. This is verified by determinations of the content of soluble nitrogen of different soil layers at various spots.

Crop yields can be forecasted if the rainfall in the foregoing period is known. This means a warning to the farmers especially when the conditions are critical. Our research is therefore directed to the detection of soil factors responsible for the indirect relation between weather and plant growth. It is hoped that more adequate advice concerning the management of soils and crops can be given in order to eliminate yield *fluctuation* as far as *possible*.

It may be concluded that the omission of soil aspects in *investigations* concerning *relationships* of *weather* to crop yield has limited the value of such studies. It might be said that the most important factor has been left out of consideration.

Résumé

Omission de la fertilité du sol dans les relations entre les conditions météorologiques et le rendement des cultures (F. van der Paauw)

L'agrométéorologie s'efforce d'expliquer les différences de rendement par les variations des conditions météorologiques régnant pendant le cycle de croissance. Elle oublie ainsi que la fertilité du sol est l'élément essentiel du rendement des cultures. Or la fertilité est une variable. Elle résulte de facteurs météorologiques dont l'action est bien antérieure au cycle de croissance. Le stock d'azote soluble est modifié en particulier par les pluies hivernales. D'autres facteurs (P, K, structure du sol, *p*H, intensité de la minéralisation de l'azote) se *modifient également*, mais plus lentement et cumulativement. Il en résulte une évolution ondoyante du rendement, qui correspond nettement à l'état du temps pendant de longues périodes.

Bien que la variation du rendement des cultures résultant de ces fluctuations de la fertilité du sol diminue sensiblement si l'on procède à une abondante addition d'engrais, elle n'en demeure pas moins importante. Les recherches peuvent par conséquent

porter sur la détection des principaux facteurs pédologiques jouant un rôle intermédiaire entre le temps et le rendement des cultures.

Il est apparu possible de prévoir le rendement et les besoins du sol en engrais (N, K) *sur la base des conditions météorologiques antérieures et de l'état du sol.* Les répercussions directes des *facteurs atmosphériques* sur la croissance végétale sont surestimées.

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