SOIL STRUCTURE AND CROP YIELD

A. J. LOW

(Imperial Chemical Industries Limited, Agricultural Division, Jealott's Hill Research Station, Bracknell, Berks)

Summary

Relatively little has been published in Great Britain relating yields with quantitative assessments of the structure of soils. This paper gives examples of the kind of correlations found, a selection from many years’ observations. Where the quantity of soil nutrients or disease was not a limiting factor, the yields of cereals, peas, and red beet were related to the stability of the structure which in turn depended on the number of years the soil had been out of grass.

On a soil of weak structure it was found that stabilizing, with a conditioner, the structure developed by cultivation at a moisture content below field capacity resulted in a marked increase in both yield and size grade of cauliflowers.

Introduction

Many attempts have been made to correlate crop yields with quantitative measurements of the structure of soils, but with limited success. Most of the work reported has been in the U.S.A. That structure must be a major factor in determining crop yield because of its influence on soil aeration, available water content, drainage, and root development. However, a structural state which adversely affects yield one year may not do so in another. If, for example, the available water capacity of a soil is low, a drought at a critical stage of growth may greatly reduce the yield. But in a year of adequate rainfall, this structure-related factor will have little or no influence. Probably the principal reason why measurements of structure, particularly pore-size distribution, do not provide good correlations with crop yield over a period of years on a given soil type is because of variations in rainfall. For example in one year on adjacent fields of the same soil series and type but with a very different structural state prolonged rain can produce temporary water-logging in one field where the air porosity is low at field capacity as compared with an adjacent one of good structure where it is much higher. An example showing this could happen on the Hanslope series is given by Low (1972). If a soil remains completely saturated with water for 24 hours, root death begins, according to Van’t Woudt and Hagan (1957).

An example of the interrelationship between volume per cent of soil-air (as characterizing the soil structure), rainfall, and yield of peas has been given by Peerlkamp (1961) in the Netherlands using soil conditioners to stabilize structures with different porosity. One year in May the rainfall was so heavy that the air-content became too low where the structure was ‘poor’, as compared with where it was better, resulting in poorer growth on the former. Later in the summer there was a dry period and the water loss was much greater on the soil of ‘better’ structure with the result that the yield of peas was no greater than where the
growth had been poor in May (apart from where the air porosity was very low in May and this resulted in a markedly lower yield).

Ferwerda (1951), also in the Netherlands, developed a scheme in 1946 for assessing soil structure visually using a scale from 1 to 10 (1 = very poor, 10 = very good); see also Peerlkamp (1959). In a potato experiment (Peerlkamp, 1961; Ferrari, 1949) where the assessment was 6 on Ferwerda’s scale, the yield was 20 per cent higher than on a soil where the value was 2½. The quantity of fertilizer nitrogen required to give maximum yield depended on the structure; at assessment 6 the amount required was 29 per cent lower than where the assessment was 2½.

In Britain, Batey and Davies (1971) using case histories of problems investigated by the soil scientists of the Ministry of Agriculture of England and Wales, have given yields of potatoes, cereals and sugar beet grown in adverse soil conditions, in each case comparing them with the normal yield. The differences in yield were very considerable. The primary cause of the difference is given in each case. Out of nine examples, the poorer yield was attributed to soil compaction in six, to anaerobic soil in two; both clearly involve soil structure.

Eagle (1972) surveyed the results of experiments conducted by the Ministry of Agriculture, Fisheries, and Food on their experimental husbandry farms in England and Wales since 1953, designed to test the effects of leys of 1 (called arable rotations), 3, and 9 years in ley-arable rotations. Physical measurements including plasticity limits, confined compactibility, stability to water, crumb porosity, shear strength, and draught were carried out and, apart from the last, showed more favourable soil conditions after the 3- and 9-year leys. Only on one farm, however (Gleadthorpe, where the soil is a loamy sand), were the yields of winter wheat better in a ley rotation than in an arable rotation. Yields of spring barley were better in a ley rotation on this farm also and slightly better at two others where the soils were silty loams over chalk. In 1970 at Gleadthorpe the yield of barley after 6 years of ley was 3113 kg/ha compared with 2008 kg/ha for the fourth successive barley crop (both well fertilized). At the optimum nitrogen level the yields of potatoes at one of these farms (Rosemaund) in the arable rotation was significantly lower than that on the ley–arable on a silt loam soil.

At Jealott’s Hill two ways of attempting to correlate yields with structural state have been used:

(i) Collecting field and plot observations and laboratory data concerning the structural state of soils and the relevant crop yields.
(ii) Stabilizing structural states by ‘conditioners’ and measuring crop yields.

We have collected data of the former type over many years in different parts of England and the latter on a much more limited scale.

Experimental

Several fields on each of three farms were sampled and the structural state was assessed by wet-sieving air-dry aggregates (Low, 1954, 1967). The percentage of oven-dry particles of diameter < 1 mm in water
stable aggregates of diameter $> 1$ mm was calculated. The stability to rain drop impact on moist soils was found to rank soils in the same order of stability as the wet-sieving analysis (Low et al., 1963). The term 'mineralized' nitrogen in this paper refers to the difference over a period of one year (autumn to autumn) in the total nitrogen in the 0–15 cm layer of the soil as determined by soil analysis (Ashton, 1936). The analysis was made on from two to four composite samples (each composite consisting of five sub-samples).

Cereal yields and the soil structural state

A comparison of these seems valid provided (a) nitrogen is not limiting, and the supply of all other nutrients is adequate, (b) the weather is the same for all comparisons, (c) the drainage is adequate, (d) pests and disease are absent, (e) there has been similar cropping in recent years. In the work described here two sets of data have been obtained, (i) comparison of field yields, structural stability, and amount of nitrogen 'mineralized' on the same soil series, on the same farm and year (Table 1), (ii) comparison of plot yields where a range of nitrogen rates was applied and the maximum rate of the fertilizer caused yield depression (Table 2).

Field comparisons

The observations described were made on two farms, Jealott's Hill Research Station, Bracknell, Berkshire (1948–9), and the other in the Vale of Pewsey in Wiltshire (1949–50), both in southern England. The crop on both farms was winter wheat.

The soils at Jealott's Hill where the yields were measured belong to the Windsor Series (Jarvis, 1968), developed on weathered London Clay which is covered with a loamy drift. The soils are naturally poorly drained and at Jealott’s Hill there is extensive pipe drainage. Before the 1939–45 war much of the land on this series, both at Jealott’s Hill and elsewhere, was in permanent grass. (The content of clay in the surface horizon (about 0–15 cm) is variable (20–35 per cent)). At Jealott’s Hill they varied in the 0–15 cm layer from 18 (JH85) to 34 per cent (JH86). The coarse sand (2000–200 μm) ranged from 36 (JH85) to 15 per cent (JH86) which is what one might expect with a drift covering.

Two soils are referred to in the Vale of Pewsey, Wantage (Avery, 1964), and a soil on the Upper Greensand not yet classified by the Soil Survey. The Wantage Series are well-drained soils developed on the more argillaceous beds on the Lower Chalk. In three soils described by Avery the clay ($< 2$ μm) content (0–10 cm) ranged from 30 to 36 per cent and the coarse sand (2000–200 μm) 6 to 7 per cent. At Pewsey the clay ranged from 33 (JH54) to 35 per cent (JH71) and the coarse sand 7 to 11 per cent. The soil developed on the Upper Greensand is a brown loamy sand, moderately well drained with a percentage mechanical analysis 2000–200 μm, 36·6; 200–50 μm, 30·6; 50–2 μm, 18·7; < 2 μm, 14·2.

At both Jealott's Hill and in the Vale of Pewsey fertilizer applications were small (15–30 kg N/ha, 6·5–13·0 kg P/ha, 16–32 kg K/ha). All but
### Table 1

**Comparison of yields of winter wheat with structural stability and mineralized nitrogen**

<table>
<thead>
<tr>
<th>Place</th>
<th>Field number</th>
<th>History</th>
<th>Series name</th>
<th>Variety</th>
<th>Yield kg/ha</th>
<th>Mineralized N (total N at time of sowing—total N after harvest) kg/ha</th>
<th>Relative stability* of air-dry aggregates on wet sieving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jealott's Hill</td>
<td>JH 83</td>
<td>First year after ploughing 3-year ley following 5-year arable following permanent grass</td>
<td>Windsor</td>
<td>Yeoman</td>
<td>3320</td>
<td>295</td>
<td>1.0 (standard for Jealott's Hill)</td>
</tr>
<tr>
<td></td>
<td>,, 85</td>
<td>First year after ploughing permanent grass up to 70 years old</td>
<td>,,</td>
<td>Holdfast</td>
<td>3080</td>
<td>1576</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>,, 84</td>
<td><strong>»</strong></td>
<td><strong>»</strong></td>
<td>Holdfast</td>
<td>4310</td>
<td>1368</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>,, 82</td>
<td><strong>»</strong></td>
<td><strong>»</strong></td>
<td>Holdfast</td>
<td>5000</td>
<td>684</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>,, 86</td>
<td><strong>»</strong></td>
<td><strong>»</strong></td>
<td>Holdfast</td>
<td>4930</td>
<td>739</td>
<td>3.2</td>
</tr>
<tr>
<td>Vale of Pewsey</td>
<td>,, 91</td>
<td>Arable for some years, bare fallow in summer before Bersee sown.</td>
<td>Frilford</td>
<td>Bersee</td>
<td>3810</td>
<td>185</td>
<td>1.0 (standard for Vale of Pewsey)</td>
</tr>
<tr>
<td></td>
<td>,, 54</td>
<td>3rd arable crop after 6-year ley</td>
<td>Wantage</td>
<td>Victor</td>
<td>1970</td>
<td>370</td>
<td>24.4</td>
</tr>
<tr>
<td></td>
<td>,, 71</td>
<td>3rd cereal crop after at least 80 years' grass</td>
<td>Wantage</td>
<td>Pilot</td>
<td>3810</td>
<td>370</td>
<td>45.0</td>
</tr>
</tbody>
</table>

* The relative stability for a given farm is calculated by making the figure for the field with poorest stability equal to unity.
one of the soils (JH91) had been in grass (Table 1). Little nitrogen was given because lodging was not unusual following ploughing of old grassland. The estimate of the quantity of nitrogen ‘mineralized’ from the soil organic matter at both sites suggested that the supply of this element should have been more than sufficient for good crops.

At Jealott’s Hill sowing conditions were good and, although all fields were not sown on the same day, the sowing was completed over a short period. In the months after sowing the rainfall was average (October to December 1948 was 194 mm—average 194 mm). This rainfall, however, is sufficient from my observations to bring about characteristic structural differences between the soils at Jealott’s Hill. The rainfall January to June 1949 was well below average (193 mm, average 280 mm) with only 14 mm in June. Thus in June, at a critical stage in the growth of winter wheat, the capacity of the crop to obtain water from the soil would be important. The better the structural state the better the root system of cereals (Low, 1972), so one would expect the wheat growing on the better structured soils at Jealott’s Hill to be better supplied with water. In addition the rainfall January to March inclusive was low (91 mm, average 146 mm) so excessive leaching of nitrogen would not have occurred. Lodging occurred only on one field (JH82), and the yield given is that assessed for the unlodged crop (the actual yield was 4400 kg/ha).

Sunshine hours were well above average (1288 April–September, mean 1069 hours).

Bearing these factors in mind the cereal yields at Jealott’s Hill in Table 1 seem reasonably in accord with the range in physical conditions indicated by the relative aggregate stabilities.

In the Vale of Pewsey results, JH54 and 71 had very different yields. The amount of nitrogen mineralized was the same but the stability of JH71 was nearly double that of JH54. JH71 was sown in early October 1949 when the soil was dry and when examined on 7 November the soil was hardly sticky and had many biopores > 200 μm in diameter (for definition of biopore see Slager, 1966) despite 167 mm of rain in October (average 77 mm). On the same day in November on JH54 mangolds were being harvested and the soil would not crumble after compressing. There were 85 mm of rain in November and the seeds were sown in JH54 in wet conditions. In the following February there were 155 mm of rain (average 57 mm). When the fields were examined at the beginning of May 1950, the soil below the surface was very wet but there were no indications of anaerobic conditions in either. In both fields at the time of the autumn 1949 sampling many worms were observed which would tend to maintain aerobic conditions. At the sampling at the beginning of May 1950, the soil in JH71 had far more visible pores than JH54. The surface of neither field was panned in May 1950.

Thus, as at Jealott’s Hill, the water-stability of the aggregates would be a major factor influencing the structural state of the soil in the spring and JH54 would have been at a disadvantage compared with 71. The different conditions at the time of sowing would also make the structural state of JH54 much poorer than 71. These differences are reflected in the yields.
JH91 is included as the results suggest that, on at least some coarse sandy soils, the structure may be adequate for vigorous growth of cereals without frequent grass breaks provided the nutrient level is adequate. The air-dry aggregates in JH91 had a very low water-stability compared with JH71 but the yields on the two fields were the same. The nitrogen 'mineralized' was much less on JH91; but the amount should have been adequate provided there was little denitrification. There were few, if any, aggregates of a size in which anaerobic conditions would occur. There were sufficient visible coarse pores for easy and good root development.

**Table 2**

Dry weight of grain and percentage recovery of fertilizer nitrogen by oats grown on an old arable and on the same soil after eight years' ley

<table>
<thead>
<tr>
<th>Rates of nitrogen kg/ha</th>
<th>0</th>
<th>46</th>
<th>92</th>
<th>138</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry weight of grain (spring oats) g/plot</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old arable</td>
<td>210</td>
<td>277</td>
<td>286</td>
<td>261</td>
</tr>
<tr>
<td>After 8 years' ley</td>
<td>264</td>
<td>320</td>
<td>316</td>
<td>284</td>
</tr>
<tr>
<td>Standard error</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant difference</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Percentage recovery of fertilizer N (grain+straw)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old arable</td>
<td>32.4</td>
<td>19.5</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>After 8 years' ley</td>
<td>37.8</td>
<td>27.2</td>
<td>15.8</td>
<td></td>
</tr>
</tbody>
</table>

**Small replicated plot trials**

The second group of observations on the effect of soil structure on yield were made in a replicated small plot trial using four rates of nitrogen. The site was on the Berkhamsted Series (Avery, 1964). This series is developed on the Plateau Gravel (or Drift) and is characterized by 'a friable pebbly surface and subsurface of loam or sandy loam texture underlain between 30 and 45 cm by mottled red and yellow clay containing varying amounts of sand and pebbles'. This describes the profile at Jealott's Hill where the soil is underlain by London Clay. In two examples given by Jarvis (1968), the clay contents (<2 μm) in the 0-15 cm horizon is 7 and 15 per cent, and coarse sand (2000-200 μm) 30 and 23 per cent. (At Jealott's Hill the analysis per cent was 2000-200 μm, 30.6; 200-50 μm, 24.3; 50-2 μm, 26.8; <2 μm, 18.3.)

In an old arable field at Jealott's Hill where the predominating crops had been cereals, the air-dry aggregates were very unstable to wetting. Thirty-two plots (each 2 m x 2 m) were marked out, emptied to a depth of 20 cm, and lined with concrete slabs 22.5 cm deep x 5 cm thick. Sixteen of the plots, selected at random, were filled with soil of the same series dug from a site 10 m away in an adjacent field which had been in grass for eight years. The other sixteen plots were similarly filled with soil from the old arable field. The work was done by hand with spades and all subsequent cultivations were done by hand. The plots were
prepared and the soil moved during a long dry period in mid-winter when the soil was moist but not wet. Care was taken to avoid compres- sion of the soil.

Spring oats: yield and the soil structural state

In the first year spring oats were sown: 0, 23, 46, and 69 kg N/ha (as ammonium sulphate) were applied in the seed bed and 0, 23, 46, and 69 kg N/ha (as ‘Nitro-Chalk’ 15.5 per cent N) applied as a top dressing. The results are in Table 2. The oats appeared healthy with no indications of eelworm. Analysis of the crop for all the macro and micro nutrients showed none to be deficient. The maximum rate of nitrogen depressed the yield. The relative stability to wetting of dry aggregates from the ley compared with old arable at the time the oats were sown was 20:1. During the preparation of the seed bed on a dry spring day, it was much more difficult to get a tilth on the old arable soil compared with that after the ley. Also while there was little change in the grassland soil as it dried during the course of the day, it became steadily more difficult to break down the clods of the old arable.

Red beet: yield and soil structural state

In the next year red beet was sown in May. The rainfall was low in June and July (about 75 mm in 10 weeks between sowing and harvesting) and growth was slow, but the type of results (Table 3) were similar to those of the oats, the difference between the mean yield of beet for the two soils being highly significant (p = 0.01). The relative stability to wetting of the dry aggregates of the ley one year after ploughing to the old arable, at the time the beet was sown, had fallen to 13:1.

<table>
<thead>
<tr>
<th>kg N/ha</th>
<th>0</th>
<th>46</th>
<th>92</th>
<th>138</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight g/plot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old arable</td>
<td>58</td>
<td>172</td>
<td>144</td>
<td>148</td>
</tr>
<tr>
<td>After 8 years’ ley</td>
<td>457</td>
<td>420</td>
<td>452</td>
<td>393</td>
</tr>
</tbody>
</table>

Peas: yield and the soil structural state

The effect of the soil structural state on the yield of peas was investigated for some years on a farm in the East Midlands of England near Oundle. The soil belongs to the Hanslope Series (Hodge and Seale, 1966) which is developed on the Chalky Boulder Clay. At this site it was mainly derived from nearby Oxford Clay. The drainage is imperfect but the fields on this farm have had an adequate system of tile drains for many years. The soil usually contains free calcium carbonate at the surface which increases rapidly with depth. The percentages of clay quoted by Thomasson (1971) range from 41 to 45 in the 0–18 cm
layer. The average percentage mechanical analyses where the peas were grown was: 2000–200 μm, 9·2; 200–50 μm, 9·1; 50–2 μm, 31·7; < 2 μm, 40·0. The peas were adequately fertilized, 78 kg N/ha, 32 kg P/ha, and 77 kg K/ha being broadcast as a compound and then worked into the seed bed. With the high clay content of this soil the concentration of P and K in the soil solution should not have been high. The yields in two fields of different structural state are given in Table 4. The peas in field JH88 were the first crop after ploughing an old grassland field while those in field JH81 were sown in an old arable field. The visible difference in structure was marked. In the field formerly in grass (88) the peds were round and porous, 3–5 mm in diameter, while in the old arable field (81) they were angular, compact, and much larger, 6–12 mm in diameter. The apparent density of JH78 (measured on cores) was about 1·1 g cm⁻³ and the old arable JH81 was about 1·5 g cm⁻³. There were far more visible biopores in JH78 than 81.

<table>
<thead>
<tr>
<th>History and no. of field</th>
<th>Series</th>
<th>Yield of peas (dried) kg/ha</th>
<th>Relative stability of air-dry aggregates on wet sieving</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-year pasture—first year after ploughing, JH78</td>
<td>Hanslope</td>
<td>4000</td>
<td>3·9</td>
</tr>
<tr>
<td>Continuous arable since 1860, JH81</td>
<td>Hanslope</td>
<td>1250</td>
<td>1·0 (Standard)</td>
</tr>
</tbody>
</table>

The difference in yield is very large. There were no indications of disease (no peas had been grown in JH81 in the previous seven years at least). From these data (and many similar on the same farm) peas appear to be one of the crops sensitive to structural conditions. (On old arable soils peas respond to applied nitrogen; the amount given should have been adequate for a good crop on JH81.)

The radicles of peas are large, e.g. 2000 μm in diameter compared with, for example, wheat—average 300 μm (Barley and Greacen, 1967). Consequently, for free ramification of the roots of peas, large pores are required. Not only were there far more visible biopores on the old grassland soil (worm activity was much greater—Low, 1972) but the 'structure produced by cultivating' was much more stable to rainfall on the old grassland so that the coarse pores produced did not collapse as in the much less stable old arable soil. This difference in porosity seems likely to have been the major cause of the difference in yield.

In the last few years attempts have been made to grow onions on the Hanslope series. This crop is very sensitive to the structural state of a soil and it has been found that it can be grown successfully on this series only in the first few years after a long period under grass. The roots of onions are very coarse, greater in diameter than those of peas, and this is probably why a structural state with plenty of stable coarse pores is required.
SOIL STRUCTURE AND CROP YIELD

Soil conditioners

The effects of soil conditioners on crop yields have been measured on the Hildenborough Series (Green, 1971). This soil is developed on the Weald Clay. At Fernhurst in West Sussex, where the work was done, the Weald Clay is high in fine sand and silt. The percentage mechanical analysis at the site of the experiment was 2000–200 μm, 6·3; 200–50 μm, 36·4; 50–2 μm, 31·8; < 2 μm, 25·5. Although quite a good tilth can be obtained by cultivating soils of the Hildenborough Series (which have been out of grass for a few years) if the moisture content is below field capacity, it is soon destroyed by heavy rainfall. On such soils it has been found possible to stabilize the ‘structure’ produced by cultivation at a moisture content below field capacity with conditioners such as Krilium.1 Krilium spread on relatively dry soil was applied at rates ranging from 678 to 2550 kg/ha, in a field trial laid out as six replicates of five treatments in a fully randomized design, and worked into the soil to a depth of 15 cm. The whole area had previously been worked to a good tilth to 15 cm with a rotary hoe.

Lettuces were grown in the first year, cauliflowers in the second, and carrots in the third. While detailed records were only kept for the cauliflowers, the best results each year in terms of crop quality were obtained with the highest rate of Krilium.

One year after the application of the Krilium the site was prepared for the cauliflowers by hand digging and very adequate amounts of fertilizers applied. Cauliflowers were planted out and the results of the treatments are in Table 5.

**Table 5**

Yield of cauliflowers in plots with and without Krilium

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total yield mean/plot Heads wt. kg</th>
<th>Size graded no. of heads and yield mean/plot* Heads wt. kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>121</td>
</tr>
<tr>
<td>Control</td>
<td>154 35·7</td>
<td>.</td>
</tr>
<tr>
<td>678 kg/ha</td>
<td>153 43·9</td>
<td>2</td>
</tr>
<tr>
<td>Krilium</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>2550 kg/ha</td>
<td>167 80·5</td>
<td>.</td>
</tr>
</tbody>
</table>

* Grading. (The grading for size, e.g. 128, 165, is the number of cauliflowers to a crate. The curd diameter of the 241 is 7·5 to 10 cm; 168, 10 to 12·5 cm; 128, 12·5 to 15 cm.)

After the crop was harvested, the bare plots were examined (19 months after application). The effect of the different treatments was clearly visible both by the difference in soil colour and the physical condition. The relative stability to wet sieving 19 months after application of Krilium was: Control, 1 (standard for this site); 678 kg Krilium/ha, 1·6; 2550 kg Krilium/ha, 25·1. A field examination of the structural state of the soil was made three years after the Krilium had been applied and indicated that the effect of the conditioner was about the same as in the first year.

1 The Krilium used was the Merloam formulation, a modified co-polymer of vinyl acetate and maleic acid (VAMA).
A search of the literature has not disclosed any work exactly comparable with that reported in this paper. In the work described by Eagle (1972) and Batey and Davies (1971) they found yield differences when the structural differences were considerable. The differences in yield reported in this paper have also been found where the differences in soil physical conditions have been considerable due either to very long periods under grass compared with little or none, to bad seed-bed conditions, or to artificially stabilized structures with different amounts of conditioner.

It is well known that some arable soils are much less stable to wetting and drying than others and two of the soils used belong to this category, the Berkhamsted and Hildenborough series. On the former there was a very marked effect of eight years of grass and the latter responded well to soil conditioners.

Marked yield differences have been found where the difference between the number of years under grass before the test crop has been considerable. If the method used in this work of assessing the amount of nitrogen likely to be available during the period of growth is valid, it seems reasonable to assume the yield differences of wheat to have been due to physical factors. As legumes, peas should be largely independent of soil nitrogen although in poorly structured soils they have been found to respond to fertilizer nitrogen. An adequate amount of fertilizer nitrogen was given to the peas grown both in the well and badly structured soils so again the large difference in yield seems best accounted for by physical factors.

No other results relating structure with the growth of cauliflowers have been found. It appears to be a very responsive crop to the structural state.

The fall in the total nitrogen in one year following the ploughing of grassland is often large. Similar results have been obtained during the course of this work in different parts of England. It is important to know the form in which this nitrogen is lost. In lysimeter work at Jealott's Hill, Low and Armitage (1970) found large falls in total soil nitrogen which could not be accounted for in the drainage water and assumed that much of it was due to denitrification.

Conclusions

The examples given show yield differences which cannot be accounted for by lack of nutrients or disease and suggest that the structural state of the soil may be a dominant factor.

Acknowledgements

The author wishes to thank Miss F. J. Piper, and Mr. P. A. Collier for their valuable assistance and Mr. G. D. Lockie, Fernhurst Research Station, for permission to quote the yield data from the soil conditioner experiment.
REFERENCES


(Received 20 April 1972)