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PORE SPACE ON THREE EXPERIMENTAL FIELDS WITH DIFFERENT PLOWING DEPTHS

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1. Introduction

Experiments on depth of cultivation have previously been carried out as early as the last century (Wollny, King). Up to now there is no satisfactory answer to the question of the influence of plowing depth on crop yield and so there are still experimental fields to study this subject. We should not be astonished at it, because for the farmer this is about the only thing he has to choose freely on soil cultivation and it is also about the only reproducible fact mentioned in many reports on soil cultivation experiments.

To-day in the Netherlands the study of the relation between soil cultivation and crop yield is split up into two parts : the relation between soil cultivation and conditions for plant growth, especially soil structure on the one hand and on the other the relation between soil structure and plant growth. So on the three experimental fields that will be discussed special attention was given to soil structure and some results of pore space determinations will be shown.

2. Experimental field PO 169

Experimental field PO 169 at Heino was laid out in 1940 on a sandy soil with a humus content of about 5 %. There are 9 plots of 7 × 24 m², 3 of them are plowed to 25 cm every year, 3 to 15 cm and 3 are plowed to 15 cm with subsoiling to 25 cm. Soil porosity determinations were made in December 1954, April and September 1955 and May and September 1957 in the layers 7-12 cm and 17-22 cm. The mean values obtained are shown in Table 1. It appears that in the topsoil porosity decreases with increasing depth of cultivation. However these differences are not statistically reliable. In the subsoil porosity increases significantly with increasing cultivation depth. So shallow plowing results in a clear increase in density of the soil at a small depth.

TABLE 1

Pore space and air content (% of volume) on PO 169

Depth of plowing .... and subsoiling	15	15 10	25
Pore space : layer 7–12 cm	49.5	48.9	48.4
layer 17–22 cm	43.3	45.9	47.1
Air content at pF 1,9 :			
layer 7–12 cm	23.3	22.4	21.7
layer 17–22 cm	13.9	17.9	19.7
—— undisturbed layer .... subsoiled layer			

In 1957, of a series of samples, the moisture content at pF 1,9 was determined. There was no clear relation between pore space and moisture content (in % of dry weight), so the mean value of 20,0 % was used to determine air content at pF 1,9 (table 1). It appears, that air content under wet conditions remains rather high, so lack of aeration is not to be expected from these porosities.

Crop production is highest on the most intensively cultivated plots. The rotation is : oats, rye and potatoes, with a green manuring crop (also rye) before potatoes. The cause of the higher production on the deeply plowed plots is still being studied. From a viewpoint of soil physics impeded aeration is not to be expected as the apparent density of the soil is low. Temporary difficulties could arise by the impeded drainage of water at the level of the sharp rise in density of the soil. Because on the plots plowed 15 cm this boundary is at a shallow depth, difficulties are to be expected first on these. However, this has not yet been examined quantatively, as could be done by the determination of conductivity for water. Other explanations of the yield differences are possible too.

3. Experimental field ZZH 691

Experimental field ZZH 691 was laid out in 1951 on a young calcareous marine clay soil at Westmaas near Rotterdam. It consists of 6 plots of 0.2 ha with plowing depths of 5, 15, 25 and 35 cm and two plots with 10 cm subsoiling in combination with 15 and 25 cm plowing. Porosity determinations were made in May and August 1955 and 1957 in the layers 7-12 cm, 17-22 cm and 27-32 cm. In 1957 water content at pF 1.9 was determined on samples from 3 plots. It appeared that at higher porosities water content in percentages of dry weight was somewhat higher than at low porosities (fig. 1).

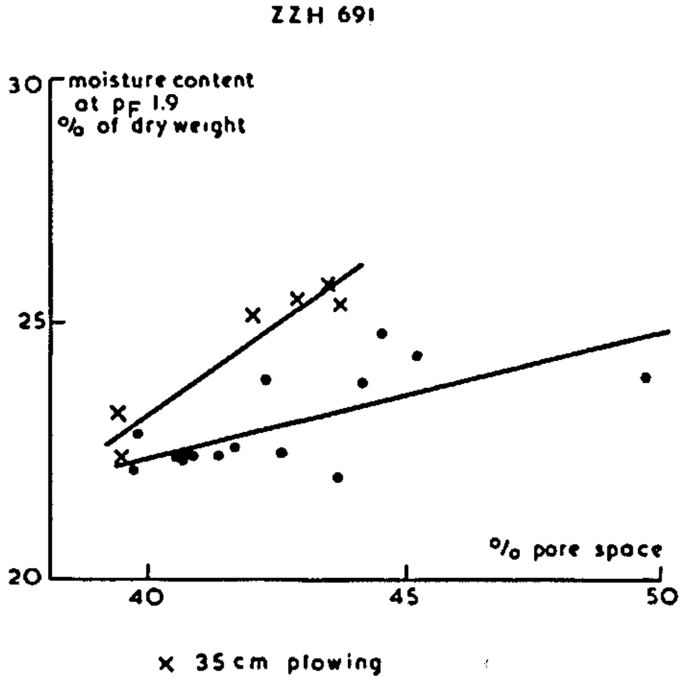

Fig. 1

Relation between water content at pF 1.9 (% of dry weight) and pore space (% of volume) on ZZH 691

TABLE 2

Pore space and air content at pF 1.9 (% of volume) on experimental field ZZH 691

Depth of plowing and subsoiling	5	15	15/10	25	25/10	35
Pore space: layer 7–12 cm	44.8	45.6	45.1	45.2	43.6	43.7
layer 17–22 cm	42.2	42.8	44.8	44.8	44.6	44.3
layer 27–32 cm	43.8	43.5	45.6	42.9	44.5	44.0
Air content at pF 1.9						
layer 7–12 cm	9.6	10.6	9.8	10.1	8.0	4.4
layer 17–22 cm	6.1	6.6	9.6	9.6	9.6	4.8
layer 27–32 cm	8.2	7.9	10.6	7.1	9.1	4.6

——— undisturbed layer
——— subsoiled layer

A linear relationship between moisture content at pF 1.9 and pore space was accepted (moisture content = 0.25 . pore space + 12,4) and in this way air content at pF 1.9 could be calculated for the mean values of pore space obtained by the periodical determinations. On the plot plowed 35 cm the soil has a different colour, is somewhat heavier and appears to be wetter in springtime than on the other plots. The relation between water content at pF 1.9 and pore space is different here (fig. 1) and could be characterized by moisture content = 0.74 × pore space — 6.3.

The results of all determinations are summarized in table 2.

It shows that in the top layer pore space is lowest at a cultivation depth of 35 cm. A difference should be 1.3 % of the volume to be reliable on the 5 % level, so generally this difference is statistically significant. In the layer 17-22 cm pore space is lowest with the shallow cultivations. In the deepest layer, the highest pore space is found at the greatest plowing depths and also on the plot plowed 15 cm with 10 cm subsoiling. It is fairly certain that this is caused by inaccuracy in regulating the cultivation depth.

Air contents show the same phenomena except that here it can be seen that the greatest plowing depth has a smaller air content caused by its higher field capacity.

On this experimental field a different crop is grown each year, e.g. sugar beets, potatoes, wheat, peas and flax. Generally speaking yields are lowest with 5 cm plowing.

Under wet conditions, say at field capacity, air content of the soil is rather low, especially in the layers with low porosity. So it is not impossible that impeded aeration influences crop production under wet conditions. The small plowing depths show a particularly sharp increase in density not far from the surface, which might cause a temporary lack of air when water is moving down by gravity.

4. Experimental field PrLov. 7

This third experimental field was laid out in 1944 on a calcareous sea bottom soil in the North East Polder. It was the first agricultural purpose this soil served. The experimental field consists of one part with plowing depths that are changed each year (36 plots) and a part on which plowing depths are constant (18 plots of 12 × 150 m^2). Each year all the six crops of the rotation are grown. Plowing depths are 12, 20 and 28 cm. The soil has a clay content of about 30 % (particles < 16 microns).

Porosity determinations are made in May and September 1955 and in May and October 1957 on the plots with permanent plowing depths on which sugar beets were grown (table 3).

TABLE 3

Pore space and air content (% of volume) on PrLov. 7

Plowing depth	12	20	28
Pore space : layer 7–12 cm	47.1	46.3	46.8
layer 17–22 cm	52.0	47.5	48.3
layer 27–32 cm	56.1	54.6	50.9
Air content at pF 1.9 : layer 7–12 cm.	5.6	4.3	5.1
layer 17–22 cm	4.7	6.2	7.4
layer 27–32 cm	6.9	5.9	4.3

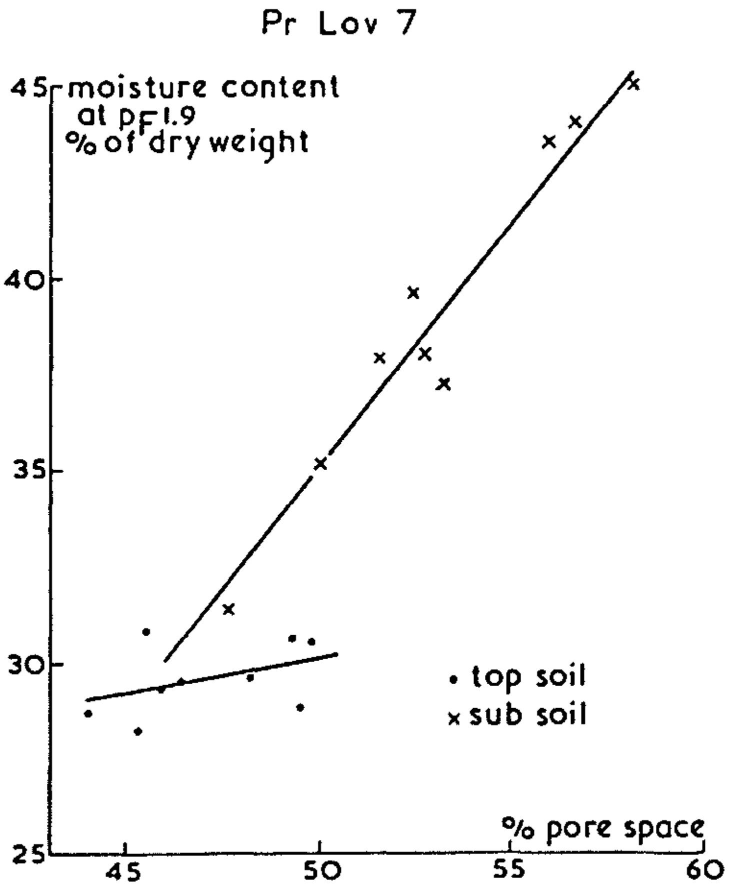

Fig. 2

Relation between water content at pF 1.9 (% of dry weight) and pore space (% of volume) on PrLov. 7

The figures that correspond to the virgin subsoil are underlined.

Pore space is much higher in the virgin subsoil than in the cultivated layers. Determinations of moisture content at pF 1.9 show that there is a remarkably clear relation between pore space and water content at pF 1.9 for the subsoil, but not for the topsoil (fig. 2).

It appears that this relation even exists at higher pressures than pF 1.9 and it is reasonable to ascribe this relation to the differences in clay content between the different samples of the set, as the virgin subsoil is built up from small layers of sand and clay alternatively.

From the relations shown in fig. 2 it is possible to calculate air content of the soil at pF 1.9 for the mean values of pore space found. The results are also summarized in table 3. It appears, that although pore space is much higher in the subsoil than in the topsoil, this is not true for air content at pF 1.9 From the latter can be seen that aeration may become difficult under wet conditions. On this soil the danger is greater than should be expected from the figures as surface crusts are easily formed.

Between the different plowing depths differences in crop production are found in several years. However there are not yet enough data to give satisfactory explanations.

4. Conclusion

The experimental fields on plowing depth mentioned above do show an influence of the depth of soil cultivation on soil physical conditions and this may give an opportunity to study the relation between soil structure and crop production as crop yield sometimes varies with plowing depth.

SAMENVATTING

Porienvolume in drie proefvelden met verschillende ploegdiepten

Op een eerste proefveld, zandgrond, werden de volgende drie ploegdiepten vergeleken : nl. 15, 25 en 15 cm met ondergrondwoelen tot op 25 cm. In de bovenste grondlaag nl. van 0 tot 15 cm, zijn de verschillen te verwaarlozen. Voor een diepte van 15 à 25 cm is het poriënvolume het laagst bij ploegen tot op 15 cm diepte en het grootst voor de diepere bewerking tot op 25 cm. De afname aan poriënvolume met de diepte in de 0-25 cm laag is dus het grootst voor het ploegen tot op 15 cm.

Op een tweede proefveld, een jonge lichte marine poldergrond, werden ploegdiepten van 12, 20 en 28 cm vergeleken. In de bebouwde lagen traden slechts lichte verschillen op. Onbebouwde lagen vertoonden een groter poriënvolume, zonder dat nochtans het luchtgehalte bij een pF van 1,9 hoger is. In de bovenste laag is het vochtgehalte bij pF 1,9 onafhankelijk van het poriënvolume, terwijl in de onberoerde ondergrond een klaar verband tussen poriënvolume en watergehalte, bij pF 1,9, bestaat. Dit is veroorzaakt door verschillen in kleigehalte.

Op het derde proefveld, met zeepolderklei, werden volgende ploegdiepten vergeleken: 5, 15, 25 en 35 cm evenals de ploegdiepten van 15 en 25 cm doch deze beide laatste aangevuld door een omgewoelde laag van 10 cm dik. De bodemlaag van 5 tot 15 cm vertoont het geringste poriënvolume bij de diepste bewerkingen; deze van 15 tot 25 cm een geringer poriënvolume bij ploegen tot op 5 en 15 cm, terwijl de laag van 25 tot 35 cm een geringer poriënvolume heeft wanneer ze niet bewerkt is.

Bij pF 1,9 is het watergehalte uitgedrukt in % op het droog gewicht eender onafhankelijk van het poriënvolume, zodat dit onder kritische omstandigheden als maatstaf voor de verluchting kan genomen worden.

RESUME

Porosité sur trois parcelles d'expérimentation avec différentes profondeurs du labour

Pour une première parcelle d'expérimentation, établie sur une terre sableuse, l'auteur compare les profondeurs de labour suivantes : 15 cm, 25 cm et un labour à 15 cm complété d'un sous-solage à 25 cm.

Dans la couche de 0-15 cm, les différences sont négligeables; dans la couche de 15-25 cm, la porosité est la plus réduite pour un labour à 15 cm et la plus élevée pour un labour à 25 cm. La porosité entre 0 et 25 cm décroit donc le plus vite avec la profondeur après un labour de 15 cm.

Sur une deuxième parcelle, établie sur une terre poldérienne jeune et légère, furent comparées les profondeurs de labour de 12, 20 et 28 cm. Les différences sont toujours faibles dans les couches labourées. Les horizons non labourés présentent une porosité bien plus élevée; malgré cela, l'aération n'est pas plus prononcée à un pF = 1,9.

Dans la couche superficielle, l'humidité au pF 1,9 est indépendante de la porosité; dans le sous-sol, resté intact, il existe cependant une relation évidente entre la porosité et l'humidité au pF 1,9, qui peut s'expliquer par des différences dans la teneur en argile.

Sur la troisième parcelle d'expérimentation, sise sur une terre argileuse d'origine marine, on compare les labours à des profondeurs de 5, 15, 25 et 35 cm, ainsi que le labour à 15 et à 25 cm, ces derniers complétés par le sous-solage d'une couche de 10 cm.

La couche de 5-15 cm accuse la porosité la plus faible pour les labours les plus profonds; la couche de 15-25 cm a une porosité plus réduite pour les labours à 5 et à 15 cm; enfin la couche de 25-35 cm a la porosité la plus faible quand elle est laissée intacte. Au pF 1,9 la teneur en eau (en % de matière sèche) semble indépendante de la porosité, ce qui veut dire que dans ce cas la porosité peut traduire l'aération en certaines circonstances critiques.

ZUSAMMENFASSUNG

Porenvolumen auf drei Versuchsfeldern mit verschiedenen Pflugtiefen

Auf einem Versuchsfeld auf sandigen Boden werden folgende Pflugtiefen verglichen : 15 cm, 25 cm und 15 cm mit Untergrundlockerung bis 25 cm.

Die Unterschiede in der Tiefe 0-15 cm sind nicht wesentlich; in der Tiefe 15-25 cm ist das Porenvolumen am niedrigsten für die Pflugtiefe bis 15 cm, und am höchsten für die Pflugtiefe bis 25 cm. Die Abnahme des Porenvolumens mit der Tiefe ist also die grösste bei 15 cm Pflugtiefe.

Auf einem zweiten Versuchsfeld, auf einem leichten jungen marinen Marschboden, werden die Pflugtiefen von 12, 20 und 28 cm verglichen. In den bearbeiteten Schichten sind die Unterschiede gering. Die nicht bearbeiteten Schichten haben ein bedeuted höheres Porenvolumen, obwohl der Luftgehalt bei pF 1,9 nicht höher liegt. In der oberen Schicht ist die Feuchtigkeit bei 1,9 von dem Porenvolumen unabhängig; in dem nicht bearbeiteten Unterboden aber gibt es eine deutliche Korrelation zwischen Porenvolumen und Wassergehalt bei pF 1,9, welche durch Unterschiede im Tongehalt zu erklären ist.

Auf einem dritten Versuchsfeld, auf marinen Tonböden, wurden folgende Arbeitstiefen verglichen: 5, 15, 25 und 35 cm; ausserdem noch die Pflugtiefen 15 und 25 cm, jedesmal mit einer gelockerten zweiten Schicht von 10 cm.

Die Schicht 5-15 cm zeigt das niedrigste Porenvolumen bei der tiefsten Bearbeitung; die Schicht 15-25 cm hat ein niedrigeres Porenvolumen bei einer Pflugtiefe von 5 und 15 cm; die Bodenschicht 25-35 cm ist ebenfalls weniger porös, wenn sie unbearbeitet geblieben ist.

Bei einem pF-Wert 1,9 ist der Wassergehalt (% der trockenen Masse) vom Porenvolumen scheinbar unabhängig, sodass hier das Porenvolumen als Masstab für die Durchlüftung unter kritischen Bedingungen gelten kann.