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THE WORKABILITY OF THE SOIL IN SPRING IN RELATION TO MOISTURE CONTENT AND MOISTURE TRANSPORT

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Abstract

Soil workability in spring is important in view of organization of work and crop yield. This property was evaluated using visual estimation, and measurements of plasticity and water content. The distribution of the water in the top layer greatly affected workability in spring; capillary transport of water plays an important role.

Data were obtained about the ideal situation for seedbedpreparation. It was shown that capillary transport was influenced by several factors. The influence of drainage and actual soil structure was studied, the former by using the results of Rijtema, and the latter by measuring the hydraulic conductivity in samples with different actual soil structure using the Arya-Ehlers method. The distribution of the water content in the top layer could be calculated by a graphical procedure, described by Bouma.

1. Introduction

For sowing or planting crops in spring, the soil must be in a condition suitable for the tillage operations desired. This means that it must be possible to crumble the upper 5-10 cm of the soil in such a way that a good seedbed is obtained and also that the whole top layer (0-20 cm) must be stable enough so that implements can be used without harmful compaction.

The earlier the farmer can have a good seedbed ready the better, because that means, certainly in West-European countries, that he has a longer period available to get his crop in and also that in most years crop growth and yields will be better.

If the farmer starts too early, at a moment that the soil cannot be crumbled and is not stable enough to resist compaction, the actual soil structure will not be optimal for good plant growth.

Therefore it is important to know when the soil satisfies the condition of good workability and how to get that condition as quickly as possible in spring.

2. Workability, moisture content, and moisture tension

It is well known that workability depends on moisture content or moisture tension. A wet soil is plastic and can easily be deformed, but not be crumbled. A decrease in moisture content results in a more crumbly, less plastic state. The moisture content and moisture tension, at which the transition occurs is an important value with respect to the workability and undoubtedly to the trafficability of the soil in spring. It fairly accurately represents the point at which the soil is suitable for soil tillage in spring. That transition value corresponds with the lower plastic limit, a parameter that was often determined in the past. Together with the moisture content in the field (or at pF 2) it gives a good indication of the workability.

Other methods exist, e.g. the use of the plasticity meter or a visual estimation (fig. 1 and 2) in combination with a measurement of moisture content and moisture tension.

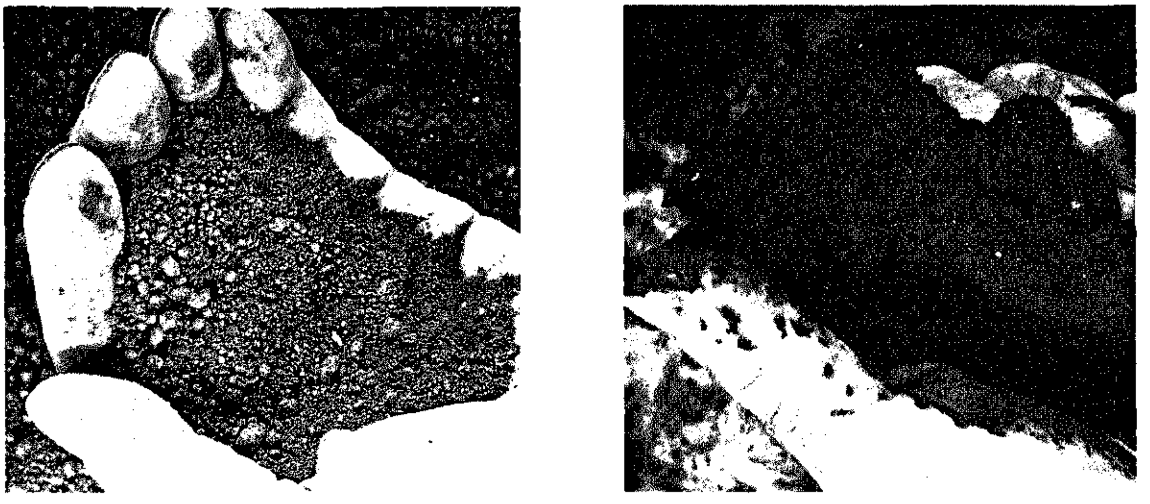

Fig. 1. Estimation of the workability of soil.

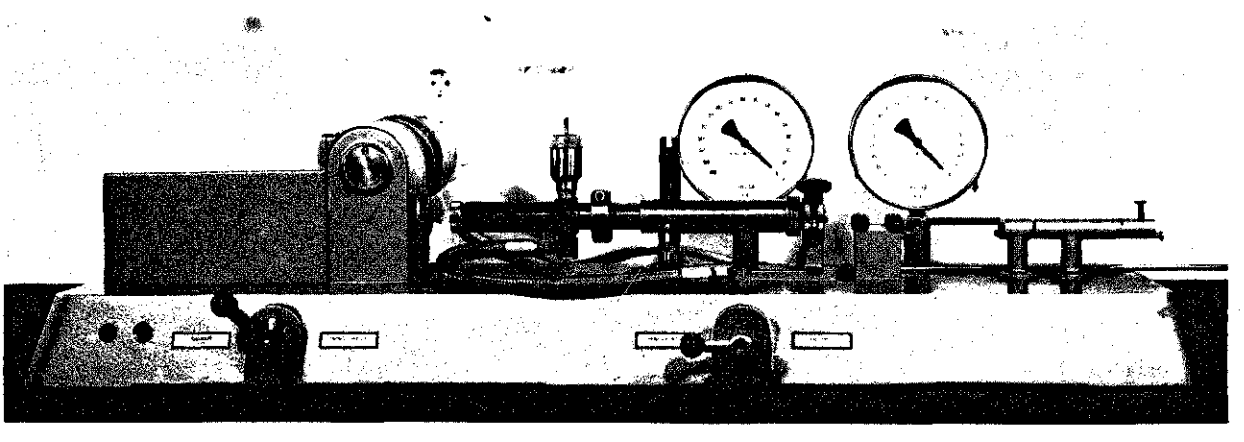

Fig. 2. Apparatus for measuring plasticity

The relation found for a clayey soil is given in fig. 3. It is known that a workability valued at 6, is sufficient for crumbling and gives sufficient resistance against pressure. This corresponds with a pressure potential of about 400 cm (pF 2.6). But what can be done with this result in the field?

3. Moisture content in the field

Most years the moisture content of the topsoil in early spring is higher than the threshold value mentioned before. This water surplus depends on soil type and depth of water table. It must be removed by evaporation. But this results in a situation with an uneven

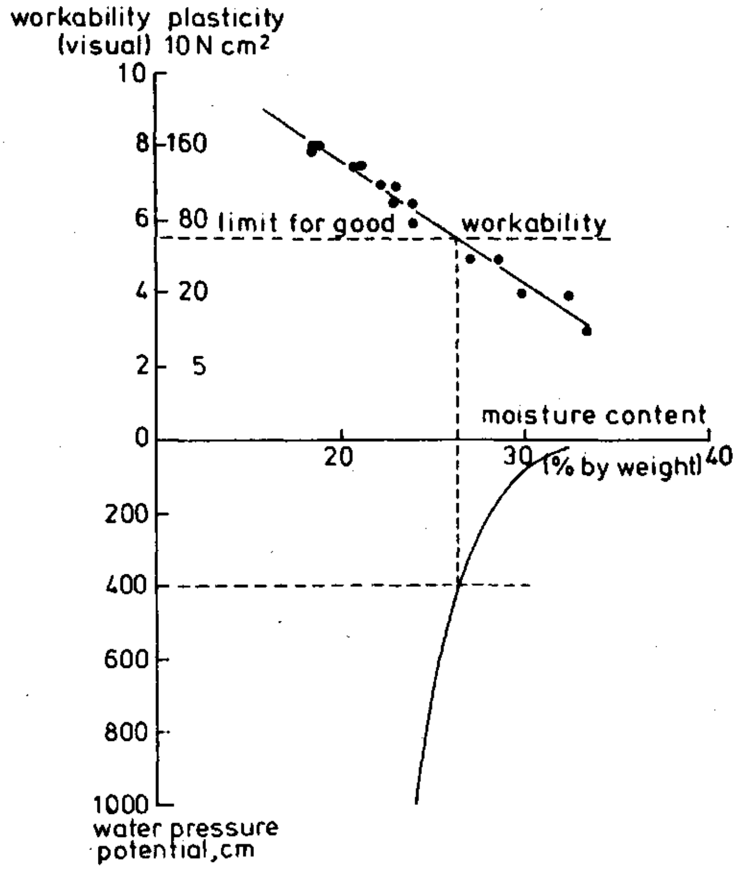

Fig. 3. Relation between workability, water content and moisture tension

distribution of water content and water tension in the top layer. The differences in moisture content in the top layer after a few days of evaporation depend on the possibility of moisture transport in the unsaturated zone. If transport is large, a rather uniform moisture distribution can be expected, if it is low this is not the case (fig. 4).

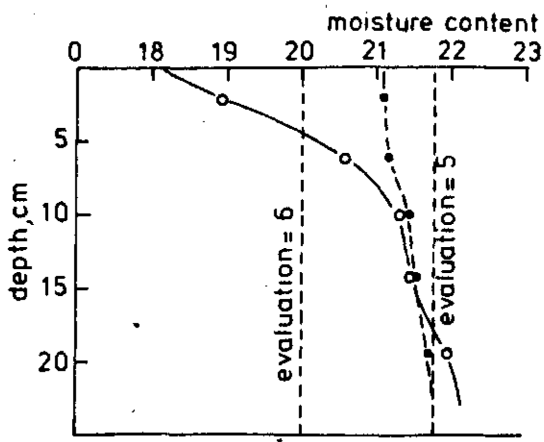

Fig. 4. Moisture distribution in the top layer as a result of differences in capillary water transport.

Then the question arises which moisture distribution is desired or acceptable in spring for the preparation of a good seedbed.

4. Moisture distribution and seedbed preparation

To prepare a good seedbed, the upper 5-10 cm (thickness depending on the crop and the accessory tillage) must be dry enough for crumbling; this means that the workability value must be 6^- or more. The next 10-15 cm must be dry enough to prevent harmful compaction. The question was which condition was acceptable and which conditions had sufficient resistance against the pressure of the tractor and other wheels and the vibrating action of the tillage implements. To get an impression about this some measurements were carried out in the field. The compaction of the soil in tracks of tractorwheels was determined. It was done at two points in time, when the moisture distribution in the furrow was quite different. Results obtained in several cases, are given in table 1.

Table 1. Compaction at two different soil moisture distributions.

Depth cm	Moisture content	Pressure potential	Workability value	Bulk Density g/cm^3 before tillage	Bulk Density g/cm^3 after tillage in track	Bulk Density g/cm^3 after tillage between tracks
0- 5	21.3	1000	6^+	1.10	1.25	1.16
5-10	30.1	120	5			
10-15	33.3	80	5^-	1.18	1.26	1.23
15-20	33.5	75	4½			
20-25	35.8	70	4½			
0- 5	26.6	400	5½	1.14	1.37	1.18
5-10	29.4	150	5			
10-15	31.8	100	5	1.17	1.39	1.12
15-20	31.6	100	5			
20-25	31.6	100	5			

On a soil with a rather dry top layer of 5 cm - low moisture content and high workability value - compaction in tracks of wheels is much less than on soils with a more uniform moisture content distribution in the top soil but with a higher value in the top 5 cm. This indicates that a dry layer with a more than sufficient workability value (6-6½) protects the deeper layers against compaction, also when these layers are rather wet and plastic (workability value 4½-5^-). Another advantage of this situation is that only a small amount of water has to be removed (difference is 5 mm) and more water is left in the soil for germination and first growth of the plants.

5. Factors affecting moisture content and moisture transport

It is well known that factors like composition of the soil and drainage have an effect on content and transport of water. Especially drainage was found to be an important factor. From values of moisture content and hydraulic conductivity in table 2 it can be concluded that surplus of water as well as hydraulic conductivity plays a part here.

Table 2. Some values of moisture content and hydraulic conductivity of a silty clay soil with a groundwater table at 30 and 100 cm, K_o= 1.5 cm/day, α= 0.024, according to Rijtema

	with groundwater table in spring at	
	30 cm	100 cm
moisture content in equilibrium with the groundwater table (vol %)	41.0	37.2
workability limit (vol %)	34.5	34.5
surplus of water (vol %)	6.7	2.7
hydraulic conductivity (cm/day)	1.4	0.14

In view of the fact that content and transport of water are affected by the composition of the soil (organic matter and clay content, lime status) it was to be expected that actual soil structure (spatial arrangement of the particles) also affects these properties. It is a known phenomenon in practice, but the question is which situation is needed to get a hydraulic conductivity, which is small enough to prevent replenishment of the loss of water by evaporation in the top 5-10 cm. To get some information about this, the hydraulic conductivity of soils with different actual soil structure was determined. For this purpose the method described and used by Ehlers was used. In this method, a core sample is exposed to a warm air stream, giving a high rate of evaporation. After about 15 minutes the moisture distribution is determined and the hydraulic conductivity at several suctions can be calculated. Fig. 5 shows relationships between hydraulic conductivity, K, the pressure head, h, for the same soil but with a different actual soil structure.

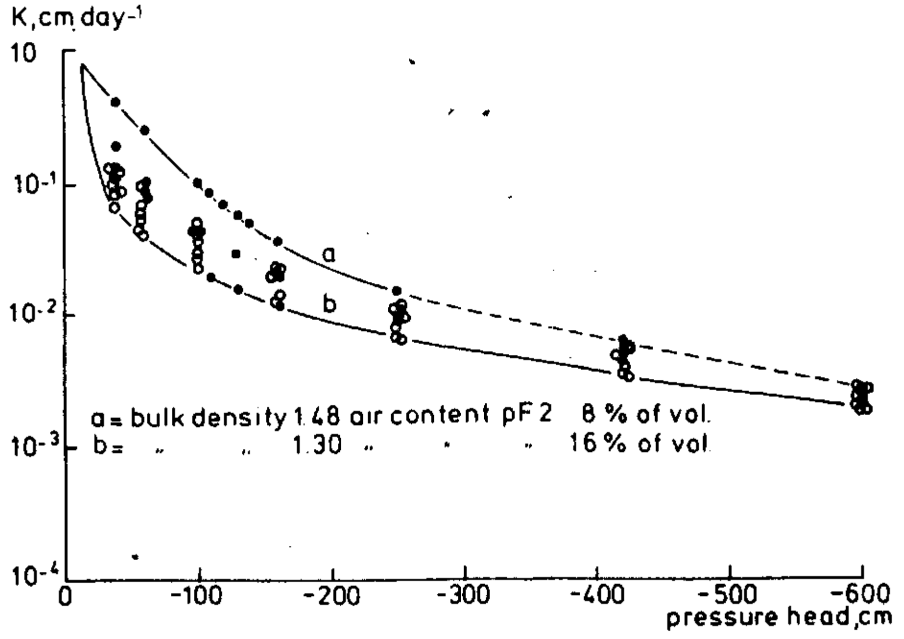

Fig. 5. Effect of actual soil structure on capillary water transport

From these relationships and with the use of a simple graphical procedure described by Bouma and based on the formula:

$$Z_n = -\int_{ho}^{hn} \frac{dh}{1+\frac{V}{K}}$$

in which Z_n is the height above a reference level at which the pressure hn is to be found, K is the hydraulic conductivity, (cm day^{-1}) and V is the flux (cm^3 cm^{-2} day^{-1}), the height above a reference level at which a certain pressure head hn will occur can be calculated.

Taking as reference level the bottom of the top soil layer of 25 cm having a suction of 100 cm water, and choosing a steady flux v. of 0.15 cm (a normal evaporation in spring) the results shown in fig. 6 are obtained.

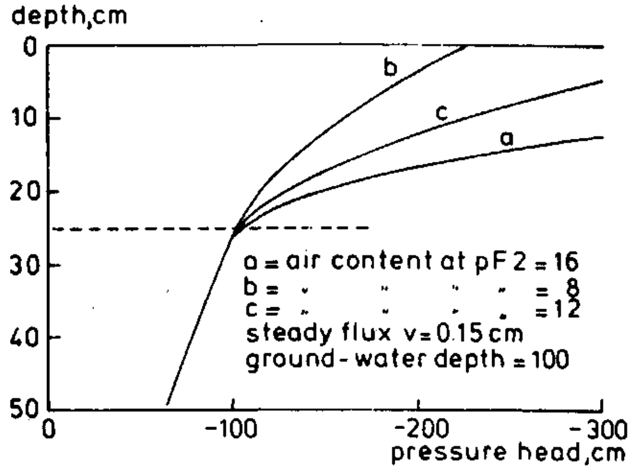

Fig. 6. Influence of actual soil structure on moisture distribution in top layer.

A rather loose soil with a bulk density of 1.32 g cm^{-3} and an air content at pF 2 of 16% by volume reaches the desired situation in a few days of dry weather and an evaporation of a few millimeters, where a dense soil with a bulk density of 1.50 and volumetric air content of 8% gets a pressure head in the top 10 cm of -160 to - 220 cm water. This is much too high for a good workability.

This means that for sufficient and fast drying up of the topsoil in spring, this clayey soil must have an actual soil structure with a volumetric air content of about 15%. There are indications that for sandy soils the same is true. Of course it is not necessery for the whole topsoil of 25 cm to have such an actual soil structure, but this will be sufficient for the top 5-10 cm. Against this background it is an interesting task to determine which soil tillage system must be used to arrive at the required situation.