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DEVELOPMENT OF A NEW LABORATORY METHOD FOR THE DETERMINATION OF SOIL CRUST STRENGHT

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DEVELOPMENT OF A NEW LABORATORY METHOD FOR THE DETERMINATION OF SOIL CRUST STRENGHT

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ABSTRACT

The mechanical impedance of soil seals or soil crusts has been defined in terms of "modulus of rupture" of artificially prepared soil briquets. Many investigaters expressed grave doubts about the application of laboratory results from the modulus of rupture technique to field conditions.

A new method was developed to overcome the basic faults of modulus of rupture and to determine the soil crust strenght simulating the emergence of seedlings in laboratory conditions. This new method was based on the establishment of soil crusts in containers under artificial rainfall, and puncturing the crusts from underneath with pre-positioned probes in the containers. With some modifications, standart "modulus of rupture apparatus" were used for the measurements. Direct measurement of the strenght of soil surface seal would be desirable because the force applied to puncture the crust would be comparable with the forces exerted by emerging seedlings.

INTRODUCTION

The mechanical impendance of soil seals or soil crusts is one of the primary factors effecting seed germination and emergence. Soil crust, as 1 to 5 mm thick compact layer of soil on the surface, reduces soil aearation, decreases water infiltration rate and thus favurs water erosion

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due to incroased surface runoff (8,10,19).

The formation of soil crust is due to the compaction of soil surface for various reasons. Any mechanical effect disturbing the structure of the soil surface may cause crust formation. The disintegration of soil aggregates into individual soil particles, and recombination of these particles into a structureless mass of compact layer on the soil surface under natural rainfall and drying sequences are the primary processes in soil crust formation (9).

The formation of soil crust, its thickness and hardness or strenght depend on the intensity of the factors which disturb soil structure, and on the stability of soil structure. Therefore, the mechanical effects of raindrops and the soil properties which determine the structural stability should be considered together when dealing with soil crust formation.

Mc INTYRE (1958) outlines the crust formation as follows: a) Breaking of soil aggregates due to wetting and impact action of raindrops and dispersion of soil particles; b) Transportation of dispersed particles into pores and cracks in the uppermost 1-2 mm layer; c) Hardening of this layer due to the cementing action of transported material upon drying.

The determination of hardness or strenght of soil crusts is essential in research work on its formation and its effects on crop production. RICHARDS (1953) proposed the "modulus of rupture" technique for establishing an index for the strength of soil crusts. His method of determination of crust strength is based on the measurement of breaking resistance of artifical soil briquets. This method has received a considerable acceptance and has been used extensively. However, many investigators expressed grave doubts about the application of laboratory results from the modulus of rapture technique to field conditions (2,3,19).

In this work a new index for soil crust strength was proposed. This new index, being a measure of the resistance of soil crusts to seedling emergence, was determined by simulating the emerging action of seedlings.

MATERIALS and METHODS

In the development of the proposed technique, it was assumed that the simulation of the breaking and puncturing action of an emerging coleoptile and measurement of the force exerted by it to the soil crust would be the most logical and direct approach in determination of crust strength.

For the purpose of simulating the emerging cotton coleoptile, cylindrical steel rods, 5.9 mm in diameter and 12 mm long, were attached to 3 mm diameter steel shafts; and upper end of the rods were rounded to resemble the tip of cotton coleoptiles. The dimensions and the shape of the rods sufficiently resembled cotton coleoptile (2).

To hold be soil samples and artifical coleoptiles during crust formation and crust strength measurements, containers measuring 12x11x7 cm were fabricated using 5 mm thick acrylic sheets (Fig.1). To the bottom of each container an acrylic bushing with 3 mm hole was glued to support and guide the artifical coleoptiles. The containers were provided with drainage holes and 30 cm suction tubings.

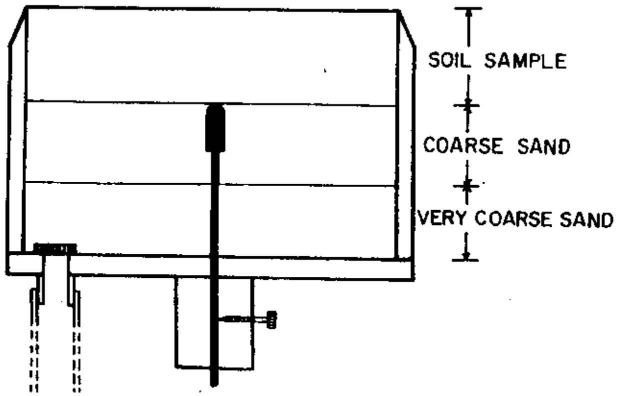

Figure 1. Soil container and the artifical coleoptile assembly.

In order to obtain soil crusts under various rainfall intensity and duration, an artifical rain maker was used. This apparatus was consisted of a raindrop former assembly and a constant level water supply tank. The presently available artifical rainmakers (1,4,5,6,7,11,12,13, 14,17,18) were rewieved and a throug consideration has been given to the factors controlling the size, uniformity and velocity of the raindrops and the overall intensity.

PROCEDURE

The artifical coleoptiles were mounted into the bushings on the soils containers; their tips being 25 mm below the upper edge of the containers. The containers were filled with 20 mm of very coarse sand (2-4 mm) and 20 mm of coarse sand (1-2 mm). Then on top of these sand layers, air dry soil samples (Ceyhan Series) which were passed through 2 mm sieve were packed to their natural bulk density. The soil samples in the containers were wetted throug the suction tubes and allowed to stand overnight under 2 cm suction.

The containers, filled with soil samples and fitted with artifical coleoptiles, were placed on a slowly rotating table, and the suction tubes were positioned for 20 cm of suction. The raindrop maker assembly was placed 10.5 m above the soil samples to assure or terminal raindrop velocity. Then rainfall of varying intensity and duration was simulated over the soil samples.

The soil samples which were subjected to artifical rainfall were placed into a forced draft oven at 40°C and allowed to dry to various moisture contents.

The crust strengths of the soil samples, expressed as their resistance to the puncturing effect of cotton coleoptiles were measured on a solution type beam balance (20 Kg capacity). For this purpose, a fixed platform was constructed above the balance plate (Fig.2). To perform the measurements, the containers holding the crust formed soil

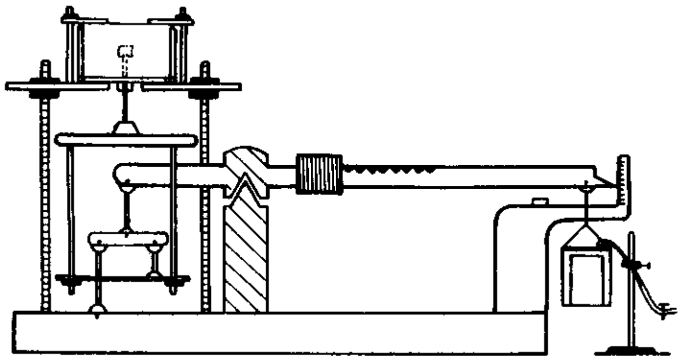

Figure 2. The experimental set-up used for crust strength measurements.

sample was mounted on this fixed platform, with lower end of the artificial coleoptile extending towards the balanca plate. A water collection vessel was hung to the end of the balance beam and metal blocks of proper thickness were placed between the lower end of the coleoptile shaft and balance plate in order to transmit the upward motion of the balance plate to the coleoptile shaft. A jet of water, adjusted to provide 2000 ml/min delivery rate, was directed to the water collection vessel. This loading action was transmitted to the soil crust from underneath it by the artitical caleoptile. When the artifical coleoptile punctured the soil crust, the water collection vessel dropped suddenly and thus the delivery of water to it stopped automatically. Than the weigth of water in the vessel was determined and divided by the cross section of the artifical coleoptile (27.326 mm^2) to calculate the strength of the soil crust, in units of g mm^{-2}.

DISCUSSION

The primary concern in this work was the determination of crust strength under a set of conditions similar to those which prevail in the field and experienced by emerging seedlings. Therefore, processes such as crust forming effects of rainfall and the pushing action of emerging seedlings on the soil crust were simulated. The results of crust strength measurements by the proposed technique, and the modulus of rupture determinations for the soil crusts obtained under similar experimental conditions are presented on figure 3.

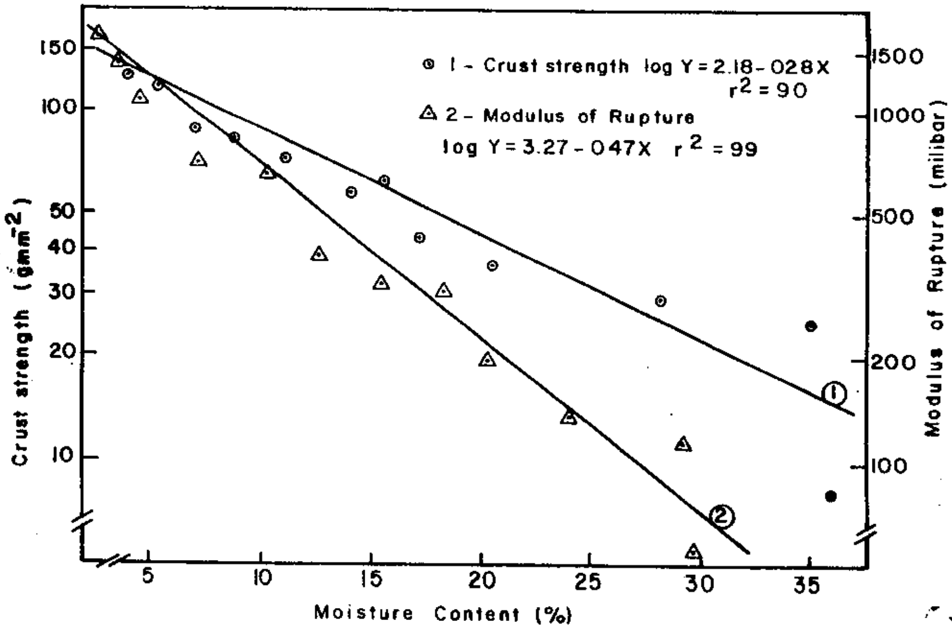

Figure 3. The crust strength and modulus of rupture as related to moisture contents for soil crusts formed under a simulated rainfall of 20 mm hr^{-1} intensity and of 1 hour duration.

Both the crust strength values and modulus of rupture are highly depended on the moisture content of soil crusts. However, this dependence on moisture content is far more pronounced in the case of modulus of rupture; probably indicating the inadequacy of the technique in the quantization of the effect of soil crusts on seedling emergence. Comparison of the proposed technique for the measurement of soil crust strength with other reported techniques, on the basis of the basic principles and procedures, may reveal its higher validity and applicability to natural field conditions. The modulus of rupture technique (15) is based on the measurement of binding strength of structural materials and the breaking force applied to the soil briquettes cannot closely reflect the force applied by the growing tip of coleoptiles. On this line of critisizm, LEMOS and LUTZ (1957) pointed out that the modulus of rupture values would not indicate the strength of soil crusts formed under natural field conditions. Furthermore the flexibility theory utilised in the above mentioned technique has been abondoned because of the limited proportionality between stress and compression along a material during bending (2). Therefore, it is highly desirable to develop a new crust strength measurement technique in which the actual breaking or puncturing action of seedlings in utilized. The technique presented in this paper seems promising both on the basic principle of measurement and on its implementation in field measurements of soil crust strength with certain uncomlicated modifications.

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