Moisture and Temperature Variation in Layered Soil Profile

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ABSTRACT

A laboratory experiment was conducted in a clay soil in Saskatoon to study the effect of layering on soil seedbed moisture and temperature variations. The treatments were subjected to a diurnal temperature and relative humidity cycle for seven days. Four layering configurations along with 3 different gravimetric initial moisture contents were investigated. Temperature and moisture content were monitored at 15, 45, 75 and 135 mm depths. Preliminary results showed that layering did not affect temperature variation in the soil profile. Layering proved to be more effective in conserving moisture in lower initial moisture content treatments and in 30 to 60 mm depth.

INTRODUCTION

The idea of deliberately creating a layered or stratified soil profile (combination of dense and loose layers of soil) has been attributed to Kolasew (1941) by Lemon (1956). The whole idea was based on the disruption of capillary tubes, forcing the moisture to move slower in a vapor form through a diffusional barrier.

Many agricultural seeding and cultivation practices produce a stratified seedbed. Tillage operations accomplished using a chisel followed by a roller and a spike tooth harrow, roughening soil surface in fallow practices and using presswheels in planting equipment will leave the top soil layered.

Retaining moisture in the seedbed is of particular relevance for small seeds which must be planted near the surface, since this is where the most variable conditions of moisture and temperature occur (Waddington and Shoop 1994). Although its importance lasts for only a couple of weeks, the seedbed plays a major role in crop establishment. Its ability to retain moisture and to conduct heat provides a proper environment for the newly planted seed. In dryland farming where a delay of one week or more after seeding before the first precipitation is not uncommon, soil undergoes a drying process. Hence, the capability of the top soil to retain more moisture and to reduce evaporative losses become more important. The idea of layering the seedbed has long been promoted (Hakansson and von Polgar 1984; Braunack and Dexter 1989; Nasr et al. 1994) and if proven to be efficient this method can easily be implemented along with other methods to reduce soil moisture loss.

This study was initiated to investigate the effect of layering on the moisture and temperature variations in the seedbed (top soil horizons) for a Saskatchewan clay soil under controlled conditions and is part of larger study in which a mathematical model is being developed.

MATERIALS AND METHODS

The soil used in the study was obtained from the Kemon research farm north east of Saskatoon. The soil is clay type (57% clay, 34% silt and 9% sand) with 4.83% organic matter content. The soil was air dried, ground and sieved (c 4.5 mm).

Experimental units (EUs) were constructed using clear acrylic tubes of 200 mm diameter and 160 mm height and solid base to allow moisture losses only by evaporation from the surface. Treatments consisted of four layering configurations, as shown in Fig. 1, and three initial gravimetric moisture contents of 27.2%, 32% and 36.8% (corresponding to 20%, 50% and 80% of field capacity, respectively). The plan was an incomplete block design of 12 treatments in 4 incomplete blocks of 3 experimental units with 3 replications.

In order to obtain uniform bulk densities across each layer, a high diameter to depth ratio was chosen by carefully packing 15 mm layers using a hydraulic press.

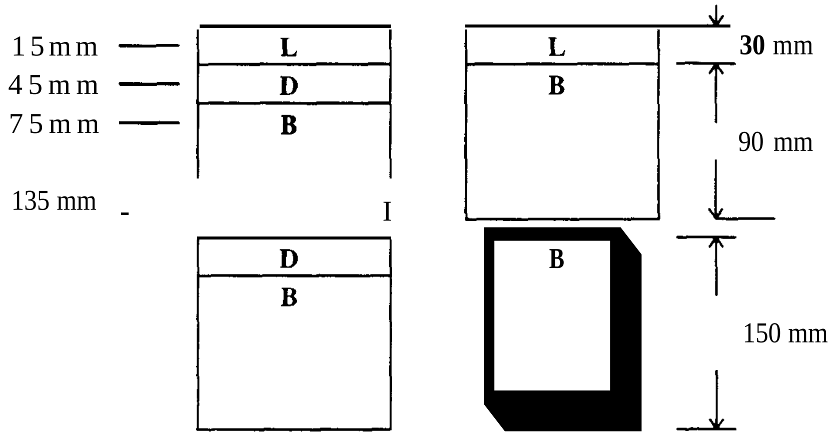

Fig. 1. Layering configurations. L, D and B stand for loose, dense and bottom layers.

Layering configurations are abbreviated as follows: B for a uniform profile; LB for a layer of 30 mm of loose soil over 120 mm of density B; DB for a layer of 30 mm of dense soil over 120 mm of density B; and LDB for 30 mm of loose soil over 30 mm of dense soil over 90 mm of density B (Fig. 1). Corresponding bulk densities of layers L, B and D are 0.95, 1.15 and 1.35 Mg/m^3, respectively.

To monitor the soil moisture in 30 mm thick layers, mini-gypsum blocks (dimensions 17x 15x 10 mm) were developed and calibrated. Temperature was measured using thermocouples. Moisture and temperature were measured at 15, 45, 75 and 135 mm depths. The temperature was also measured at the surface. EUs were insulated using fiberglass for the wall and Styrofoam at the base (Fig. 2.) and placed in a controlled

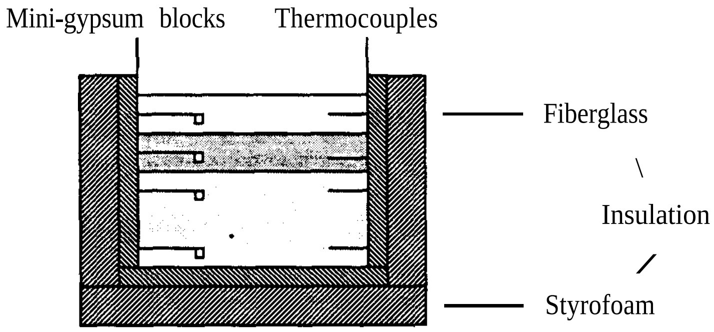

Fig. 2. Cross section of the experimental unit.

chamber in which temperature and relative humidity were set to 15 °C and 44% for 16 hours and to 5 °C and 85% for 8 hours. These settings were chosen according to local meteorological data representing the time of seeding which is usually in early May (obtained from E. Ripley, UoS, private communications). The duration of each experiment was one week. No water was added to the samples during this period. Data was collected hourly using a datalogger and stored in a computer.

RESULTS AND DISCUSSION

At this time data for one replication only, has been processed · Thus, no statistical analysis can be presented.

Temperature variations

Figure 3 shows the soil - temperature response to step changes in ambient at different depths for a sample with initial moisture content of 27.2% and LDB configuration. The trend was similar for the other treatments.

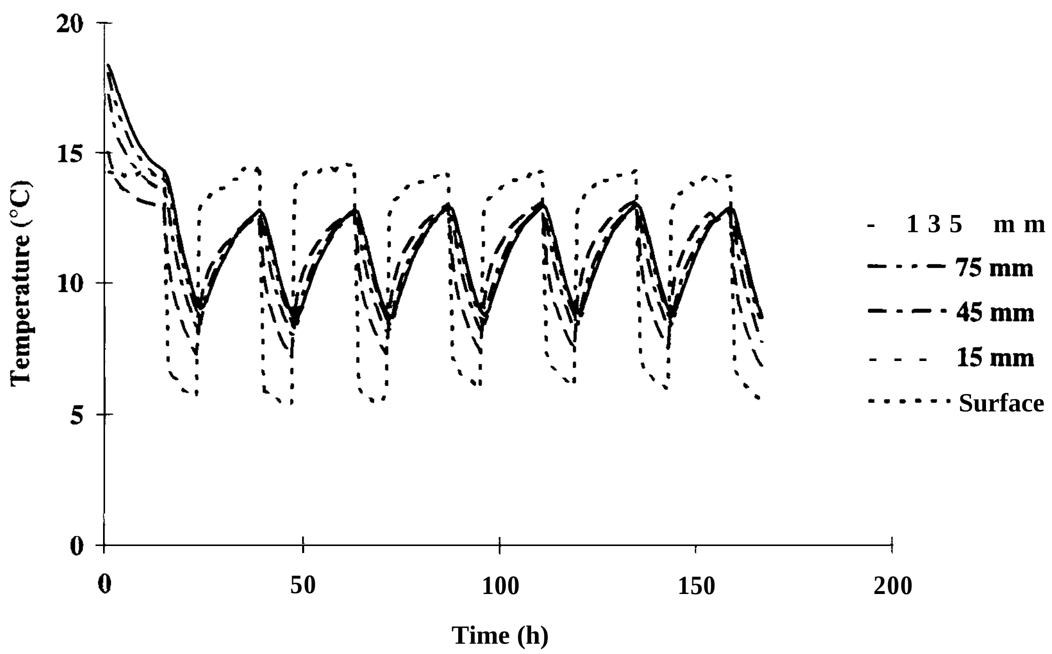

Fig. 3. Temperature variation versus time in a sample of initial moisture content of 27.2% and LDB configuration.

The graph clearly shows that after the end of the 16 hour period all layers have come to almost the same temperature. At the end of an 8 hour period only 2 °C difference between the 15 mm and the 135 mm depths was observed. Results showed that layering along with different initial moisture contents did not affect temperature variation in the soil profile down to 135 mm depth. Figure 4 is atypical graph of such results.

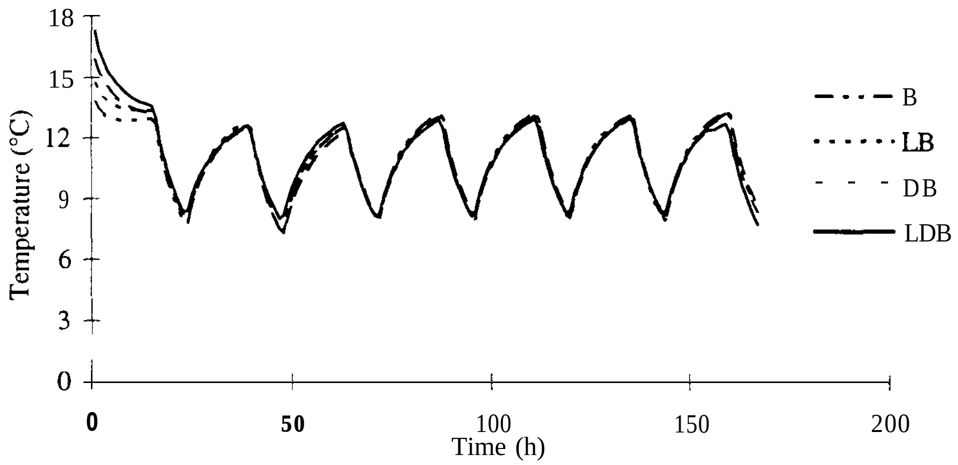

Fig. 4. Variation of temperature versus time at 45 mm depth and with initial moisture content of 27.2% in all different configurations.

Moisture variations

Figure 5 shows the variation of moisture content as a function of time. Similar graphs were obtained for other treatments. It was found that in all treatments the moisture content at the 135 mm depth was almost unchanged throughout the experiment. In higher initial moisture contents even at 75 mm depth the amount of retained moisture at the end of the experiment was not changed considerably. One of the interesting points associated with the graph shown in Fig. 5 is the occurrence of small bumps at the beginning of the cool cycle, especially at the 15 mm in the dry layer. One of the reasons for this phenomenon lies in the diffusion and transfer of water vapor from moist and warm areas to dry and cool areas. The moving force is the vapor pressure gradient. However, different ‘conditions in the soil horizons may reverse or amplify the outcome. Figure 6 illustrates the vapor movement tendencies in soil horizons of different conditions.

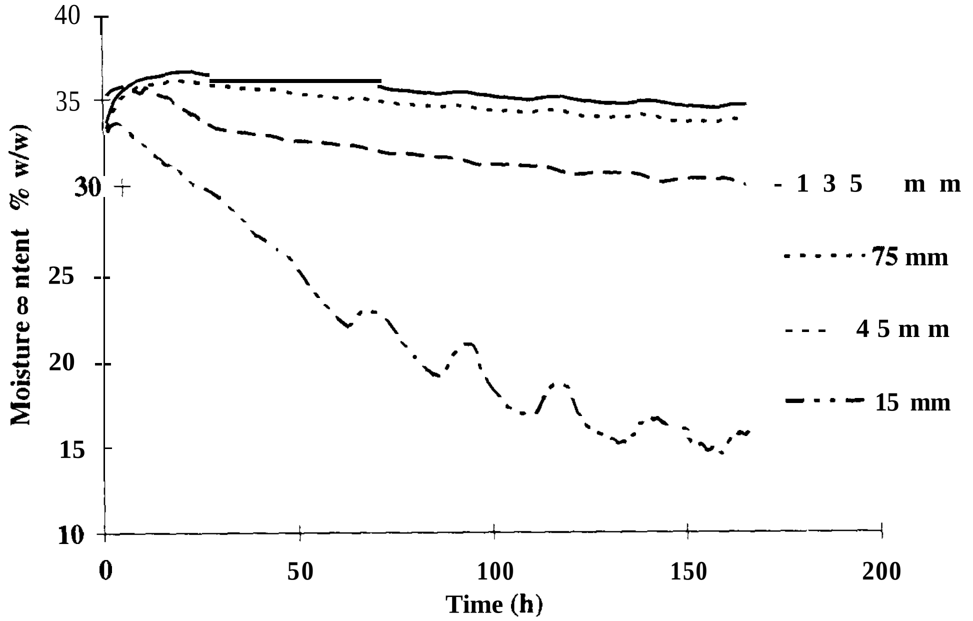

Fig. 5. Moisture content vs time with 36.8% initial moisture content and LDB profile.

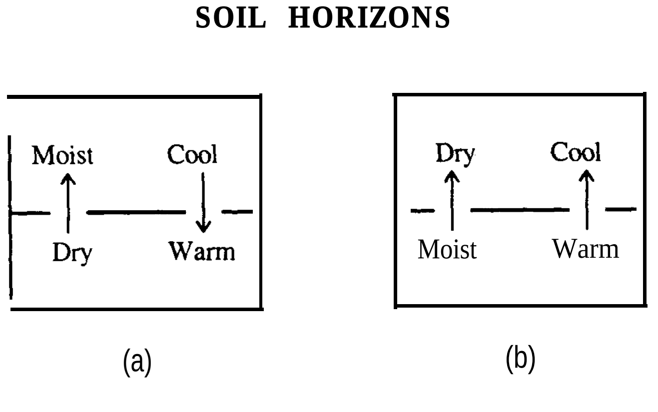

Fig. 6. Vapor movement tendencies between horizons. (a) Tendencies more or less negate each other. (b) Considerable vapor transfer might be possible if the liquid water in the soil capillaries does not interfere (after Brady 1990).

Moisture conservation was the ultimate reason for conducting this experiment and some interesting results were obtained. In lower initial moisture content, layering proved to be more effective. Also, it was found that the effect of layering is more noticeable in upper soil horizons, especially at the 45 mm depth. Figures 7 and 8 clearly show the positive effect of layering on moisture conservation at 45 mm and 75 mm depths of different configurations and initial moisture content of 27.2%. At the beginning of the experiments, depending on the initial state of the mini-gypsum blocks a certain amount of time was required for equilibrium as seen by the rising portion of the graphs. In Fig. 7 the LDB and LB configurations showed the best results. Almost 3 percentage units of moisture was conserved at the 45 mm depth with LDB configuration. This corresponds to 13.6% more moisture with respect to the uniform or B configuration. The reason for having less moisture at the 45 mm depth in the DB configuration may lie on the increased hydraulic conductivity due to the increased bulk density. Hence, higher evaporative losses from the surface.

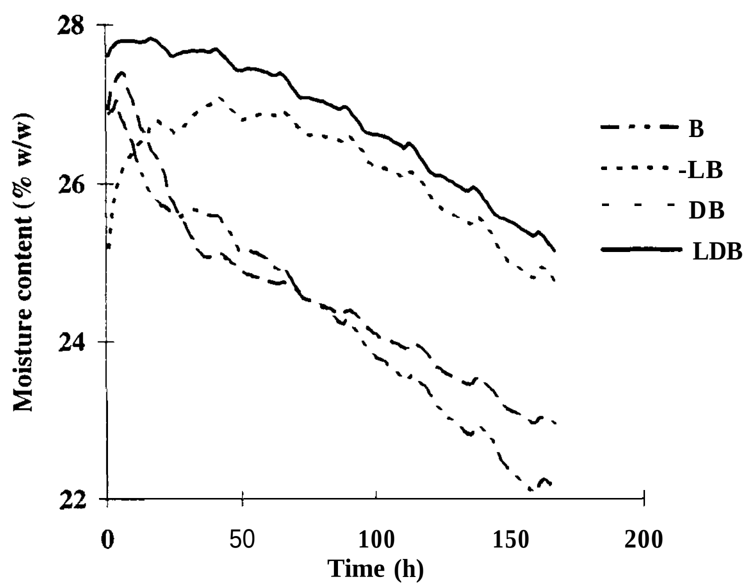

Fig. 7. Variation of moisture content as a function of time at 45 mm depth and initial moisture content of 27.2 % in all possible configurations.

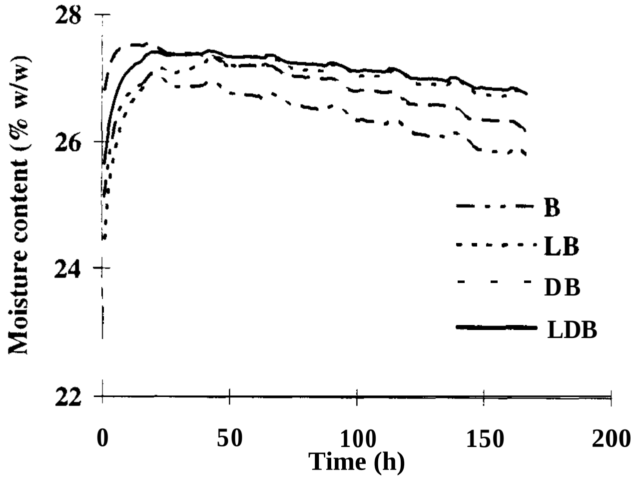

Fig. 8. Variation of moisture content as a function of time at 75 mm depth and initial moisture content of 27.2% in all possible configurations.

In Fig. 8 (corresponding to the deeper soil horizon) a similar trend was found, but with much less difference in moisture contents. One of the reasons for having less moisture variation in lower soil layers is due to the fine texture of the soil used. The high proportion of micropores in clay soils retards the liquid water movement, hence, more moisture is retained in the soil. We suspect that if a loamy soil had been used the results might have been enhanced and deeper horizons could have been affected by layering as well.

SUMMARY

Based on the preliminary results shown the following observations were made:

1. Layering did not affect the temperature variation in the soil profile.
2. The effect of layering was attenuated in deeper horizons.
3. Layering proved to be more effective in conserving moisture in treatments having lower initial moisture contents.

Further investigations along with statistical analysis are needed to verify the results of this study.

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