Mechanism of crust formation on a soil in central Iran

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Abstract

Crust formation on soils around Isfahan reduces infiltration and seedling emergence in cultivated lands. Mechanism of crust formation on local soils was investigated under field condition. Soil and crust samples from a field under furrow irrigation were taken for physical, chemical and micromorphological analysis. Seedling emergence of sugar beets (Beta vulgaris) reduced by 50% due to crust forming after the first irrigation. Rise of water table, increase of exchangeable sodium percentage to 6.4, and higher silt content resulted in higher susceptibility of soil to crust formation. Crust forming inside furrows was thicker and usually consisted of 3 layers as compared to a thinner crust formed on beds with only 2 layers. Layers found in crusts of Lavark soil generally had less sand and more silt and fine clay compared to the overall Ap horizon. Silt and fine clay in the middle M2 layer of crust forming on furrows were increased from 51.6 and 5.6 to 59.8 and 21.1 percent respectively. Percolation of finer particles through and inside the pores created layers that were denser and less porous. Chemical dispersion of particles together with physical deterioration of surface structure by long period of mechanized agriculture in the area are probably the main reasons for crust formation.

Introduction

Crust formation is a major problem on many soils of cultivated land in arid and semi-arid parts of central Iran. Surface crusts are usually thin (<2 mm to 3 mm) and have greater density, finer pores, and lower saturated hydraulic conductivity than the underlying soils (Shainberg and Singer, 1985).

Arshad and Mermut (1988) reported three kinds of crusts: i) disruptional crust, formed due to breakdown of soil aggregates under rain-drops in silty soils; ii) sedimentational crust, formed on soil from surface runoff; iii) laminar crust, forming in clayey soils with high exchangeable Na and Mg. Shainberge and Singer (1985) recognized two kinds of depositional crusts: one made of flocculated particles and much faster permeability, and the second made of dispersed clay and silt particles. The former formed in a soil with low exchangeable sodium percentage (ESP < 5) and the latter formed in a soil with higher ESP and lower electrical conductivity (EC < 0.3 dS m⁻¹). Agassi et al. (1981) reported chemical dispersion reduces sharply in soils with low ESP (~5) when electrolyte concentration increases to 5 meq L⁻¹.

The micromorphology of soil crusts has been studied with the aid of optical techniques (Arshad and Mermut, 1988; Evans and Buol, 1968; Le Souder et al., 1990). Scanning electron microscopy (SEM) has also been used to examine undisturbed soil crust sections (Chen et al., 1980; Moore and Singer, 1990; Onofio and Singer, 1984). Soil micromorphology together with the aid of physical and chemical analysis of soil crust can be used to better understand the mechanism of crust formation. The objective of this study was to examine factors influencing crust formation on a soil in field condition around Isfahan.

Materials and methods

The study area is located in central Iran within Isfahan Province (Fig.1). Lavark soil (fine-loamy, mixed, thermic Typic Haplargids) was chosen for this study.
Table 1. Physical and morphological properties of Lavark soil

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Bulk Density (Mg m(^{-3}))</th>
<th>Structure(^a)</th>
<th>Pores(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-20</td>
<td>sil</td>
<td>28</td>
<td>52</td>
<td>20</td>
<td>1.73</td>
<td>Massive</td>
<td>If dis.i</td>
</tr>
<tr>
<td>Bw</td>
<td>20-50</td>
<td>cl</td>
<td>31</td>
<td>36</td>
<td>33</td>
<td>1.74</td>
<td>1c sbk</td>
<td>1m con.i</td>
</tr>
<tr>
<td>Bt</td>
<td>50-100</td>
<td>cl</td>
<td>24</td>
<td>31</td>
<td>45</td>
<td>1.5</td>
<td>2c sbk</td>
<td>2m and c con.t</td>
</tr>
<tr>
<td>Btb</td>
<td>100-150</td>
<td>sicl</td>
<td>18</td>
<td>41</td>
<td>41</td>
<td>1.5</td>
<td>2m sbk</td>
<td>2c con.t</td>
</tr>
</tbody>
</table>

\(^a\)Structure and pores are described using USDA-SCS abbreviations.

Infiltration measurements were replicated at three sites within the field. To measure infiltration with minimum disturbance soil surface was covered with plastic and was slowly removed as soon as water was applied. Seedlings were counted after thinning in 10 m interval on beds to compare emergence in areas with crust and with no crust. Crust samples were collected from different parts of the field after each irrigation for micro-morphological observation.

Undisturbed crust samples were impregnated with Petropoxy-15 resin (Palous Petro Products, Palous, WA) for thin section preparation. Warm Petropoxy was applied directly to a warm crust sample to aid resin absorption. Due to the abundance of discontinuous pores in the crust layers, impregnation under vacuum was not effective. Many successive resin applications and grinding were necessary to achieve a fully impregnated face. The thin sections were observed and photographed with an Olympus petrographic microscope.

Results and discussion

Physical and morphological properties

Lavark soil has had a history of crust formation on the surface but in recent years the problem has been more serious. Physical deterioration of surface soil is shown by massive structure, higher bulk density and less observable porosity (Table 1). The texture of surface soil has higher silt content as compared with lower horizons which has made it more susceptible to physical deterioration and crust formation. Crust usually forms after the first irrigation. The Bw horizon also has high bulk density and weak structure probably due to compaction with heavy machinery. The area under study has been under mechanized agriculture in the past 30 years.