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Predicting Penetrometer Resistance from the Compression Characteristic of Soil

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Soil compaction is a serious issue that affects the growth of crop roots. Penetrometer resistance is often used as an indicator of the resistance of soil to root elongation. We developed a simple function to estimate penetrometer resistance from the soil compression characteristic. Five soils with contrasting textures and organic matter contents were used in this work. Air-dry soil samples were saturated on a tension table and then drained to different matric potentials not less than −30 kPa. The equilibrated soils were compacted in a uniaxial compression device to give precompression stresses in the range of 30 to 1000 kPa. The penetrometer resistance of the soils was then measured with a 2-mm-diameter 60° cone penetrometer. Soil compression characteristics varied with soil texture, organic matter content, and initial soil water content. Penetrometer resistance values increased with decreasing void ratio and could be explained by the precompression stress and the slope of the compression characteristic, using a simple equation with parameters independent of soil type. Our equation explained 84% of the variance in penetrometer resistance.

Crop growth is sensitive to soil structure because that determines the abiotic stresses experienced by the roots as well as the ability of the soil to transport water and nutrients to the roots. One of the most widely reported factors that contributes to poor soil structure is soil compaction (e.g., Fritton, 2008), and in pot experiments poor crop growth is often associated with increased soil strength (Bingham and Bengough, 2003). Håkansson (1990) proposed that the degree of soil compaction significantly influenced crop yield. In the field, however, soil compaction does not always reduce crop yields (Whalley et al., 2008). In some cases, the effects of compaction have been found to be cumulative, with lower yields only becoming manifest following repeated compaction of the same field (Sweeney et al., 2006). It should be noted that water availability to roots will also be affected by compaction via changes in the soil water release characteristic (Gregory et al., 2010) and in the hydraulic conductivity characteristic (Matthews et al., 2010).

Penetrometer resistance provides a useful indicator of the ease with which roots penetrate the soil (Dexter et al., 2007) and is closely related to the effects of soil strength on crop growth; however, we need to better understand the main factors determining penetrometer resistance in field soils that have been compacted to different extents and under a range of matric potentials. It is therefore desirable to develop a generally applicable equation to predict the effect of compression pressure on penetrometer resistance, Q.

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