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Is least limiting water range a useful indicator of the impact of tillage management on maize yield?

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ABSTRACT

Tillage management is a key factor driving changes in soil physical properties (SPP) and crop yield around the world. However, there is a lack of knowledge about the relationships between SPP and crop yield. The dynamic of SPP during the growth period is also seldom taken into account to understand suitable soil physical environment for crop growth. Moreover, the crop growth process cannot be explained by an individual SPP substantially. The least limiting water range (LLWR), which integrates soil penetration resistance, air porosity, and soil water potential, may provide a better understanding of soil-crop relationship, especially in regions with limited precipitation. Our objective was to explain how dynamic SPP affected grain yield during the growth period. A long-term field experiment was established in 2003, with continuous spring maize, on sandy loam soil. Seasonal changes of SPP (i.e. bulk density, penetration resistance, porosity, mean weight diameter, LLWR, and plant available water) were determined under reduced tillage with residue incorporated (RT-RI), conventional tillage with residue removal (CT), and no-tillage with residue mulch (NT-RM). The results showed that these SPP were affected by both tillage management and growth stage. Bulk density, porosity, S index, and mean weight diameter were not effective indicators to explain the changes of grain yield under the three tillage managements. The range of LLWR was narrower than plant available water (PAW) during the growth period and more sensitive to assess soil water availability under RT-RI, CT, and NT-RM. NT-RM significantly increased the lower limit of LLWR, which made it more difficult for root water uptake. Hence, RT-RI presented higher corn yield compared to NT-RM, even if the water content remained lower. Redundancy analysis further indicated that maize yield was mainly driven by lower limit of LLWR and penetration resistance. Overall, LLWR was an aggregative indicator including not only soil penetration resistance but also air porosity and soil water potential, which can better explain the change of grain yield under the long-term tillage management in semi-arid region.

1. Introduction

A primary challenge of our time is to attain high food security for a growing world population with reduced investment and ensuring environmental sustainability (Connor and Mínguez, 2012; Godfray and Garnett, 2014). Conservation agriculture has received wide international attention to address this challenge because of its effect on soil physical properties (SPP) (Biazin et al., 2011; Gao et al., 2019) and agricultural crops (Hobbs et al., 2007). SPP, which are variable with planting time (Afzalinia and Zabihi, 2014; Valle et al., 2018), have direct and indirect effects on the availability and uptake of water, nutrients, and air for plant growth (Tran Ba et al., 2016). Thus, it is essential to quantify SPP during the growth period for recognizing the factors that control crop growth.

Understanding the relationship between SPP and crop is particularly crucial in regions with limited precipitation. The effect of conservation tillage on SPP has been widely investigated, but how SPP affect crop growth is poorly understood (Filho et al., 2013). The reason why it is difficult to establish soil-crop relationship is that the results of SPP are highly variable, because of different time, space, and management

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