Le Corps professoral de

Gembloux Agro-Bio Tech - Université de Liège vous prie

de lui faire l'honneur d'assister à la défense publique de la dissertation originale que

Monsieur LI Shengping,

Titulaire d'un diplôme de *master of science in agricultural water-soil engineering*,

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,

le 19 janvier 2021, à 10h00 précises, en visioconférence :

web address: https://call.lifesizecloud.com/3702533
meeting room number: 3702533.

Cette dissertation originale a pour titre :

« Reduced tillage increases grain yield through improving soil physical properties and water use efficiency ».

Le jury est composé comme suit :

Président : Prof. J. BOGAERT, Professeur ordinaire,
Membres : Prof. A. DEGRE (Promotrice), Prof. X. WU (Copromoteur - CAAS, Chine), Prof. G. COLINET, Prof. E. PLOUGONVEN, Prof. B. ZHANG (CAAS, Chine).

A primary challenge of our time is to attain high food security for a growing world population with reduced investment and ensuring environmental sustainability. Conservation tillage practices have received wide international attention to address this challenge because of their effect on soil physical properties and grain yield. However, there is a lack of knowledge about the relationships between soil physical properties and grain yield, especially for soil water repellency. The dynamic of soil physical properties during the growth period is also seldom taken into account to understand suitable soil physical environment for plant growth. Moreover, although it is well known that conservation tillage practices could affect soil water repellency through hydrophobic substances and pore structure, most of the studies have only focused on hydrophobic substances due to the complexity of soil pore structure measurement and quantification. This results in limited knowledge about the relationship between soil pore structure and soil water repellency.

In this study, we used a long-term field experiment located at the Dryland Farming Experimental Station in Shouyang, Shanxi Province, in northern China to study the seasonal changes of soil physical properties (e.g. bulk density, penetration resistance, porosity, mean weight diameter, least limiting water range, and plant available water). We also assessed how these soil physical properties influence grain yield, especially reveal the mechanism of how soil water repellency affects grain yield from the perspective of soil water availability. To better understand the effects of hydrophobic substances and pore structure on soil water repellency, another long-term experimental location was conducted in Gongzhuling, Jinlin Province, northeast China. The treatments were conventional tillage with residue removal (CT), reduced tillage with residue incorporation (RT), and no-tillage with residue mulching (NT) in both of the fields. The main results of this thesis are as follows:

(1) Soil physical properties (e.g. bulk density, penetration resistance, pore size distribution, mean weight diameter, least limiting water range, and plant available water) were significantly influenced by tillage management, soil depth, and growth period ($P < 0.05$). At 0-5 cm layer, NT was the highest in soil bulk density on April 27th, but there was no significant difference among the three tillage management on July 7th, and NT was lower than RT and CT on September 10th. In addition, bulk density, porosity, S index, and mean weight diameter showed irregular and different relationships with grain yield during the growth period, especially there were no significant relationships between these soil physical properties and grain yield ($P > 0.05$). These results suggested that these soil physical properties were ineffective indicators for grain yield. In addition, the range of least limiting water range was narrower than plant available water during the growth period and more sensitive to assess soil water availability under the three treatments. NT significantly increased the lower limit of LLWR, which made it more difficult for root water uptake. Hence, RT presented higher corn yield compared to NT, even if the water content remained lower. Redundancy analysis further indicated that maize yield was mainly driven by a lower limit of LLWR and penetration resistance.

(2) Soil organic carbon and microbial biomass carbon, both of which are hydrophobic substances, were higher in RT and NT treatments than in CT treatment. Microbial biomass carbon had a closer relationship with the water repellency index than soil organic carbon and more fully explained the impact of tillage on soil water repellency. The RT and NT treatments increased the porosity of pores that were 55-165 μm in diameter and it had a positive relationship with ethanol sorptivity and the water repellency index, respectively. However, there was no significant link with soil water repellency properties when the pores were greater than165 μm in diameter. The RT and NT treatments increased sorptivity by enhancing porosity and connectivity, and decreased water sorptivity by increasing soil surface area, which occurred because the area and possibility of contact between hydrophobic substances and soil water increased.

(3) Both water sorptivity and water repellency index had effects on soil water availability (e.g. plant available water, least limiting water range, and soil water storage) that could affect plant growth. The effect of soil water repellency on soil water content became more obvious with the decrease in soil moisture following rainfall, which was also influenced by rainfall intensity. Although both water repellency index and water sorptivity can reflect the nature of soil water repellency, soil water sorptivity had a significant influence on grain yield, whereas water repellency index had no direct effect on grain yield. In addition, water sorptivity was the most favorable for grain yield improvement compared with soil organic carbon, mean weight diameter, penetration resistance, and total porosity.

In conclusion, the thesis reveals the mechanism of how soil tillage management affects grain yield by changing soil physical properties. We found that grain yield was mainly driven by a lower limit of least limiting water range and penetration resistance. 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 the semi-arid region. Furthermore, the effect of conservation tillage on SWR is a result of the interactions between pore structure and hydrophobic substances. It is necessary to take into account both pore structure and hydrophobic substances when studying the impacts of SWR on soil processes. SWR also had the potential influence on grain yield by changing soil water availability and the effect of SWR on crop yield was worthy of further study under conservation tillage practices. The grain yield under RT treatment was highest by increasing water sorptivity, LLWR, and WUE. From this, we conclud that RT treatment is the most effective tillage practice compared to CT and NT treatments from the perspective of grain yield.