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Soil disturbance behaviors and tillage forces as affected by working speed of bending subsoiling tool

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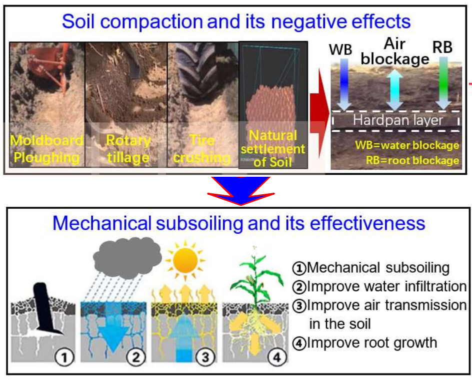
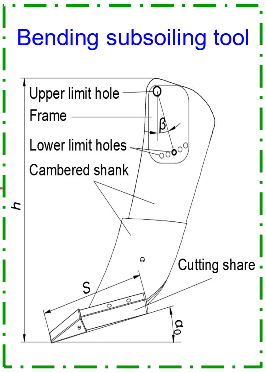
INTRODUCTION & AIM

In agricultural engineering, mechanical subsoiling is the quickest solution to removing the issue of soil compaction with intensions of restore soil productivity significantly. Bending subsoiling tool (BST) is widely utilized in field subsoiling operations. However, previous studies have been deficient in examining the effects of the BST's working speed on soil displacements at different depths and resultant soil surface conditions, soil layer mixing, and soil loosening efficiency, all of which are fundamental to improving subsoiling effectiveness of the BST.

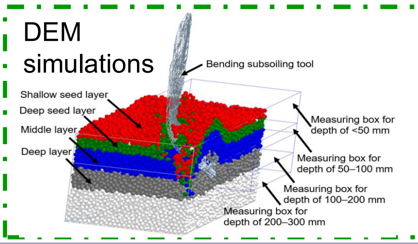
The specific aims of this study are : 1) Based on the DEM model of soil-BST interaction with working speed ranging from 1.5 to 9.5 km/h, 2) utilize the DEM model to explore the impacts of working speed on tillage forces, soil disturbance characteristics (e.g., soil surface flatness and disturbance area), and the corresponding mechanism of soil particles' microscopic movement (e.g., soil displacements and soil layer mixing), 3) offer a theoretical foundation and practical implications for understanding soil-BST interactions and determining the optimal working speeds of the BST.

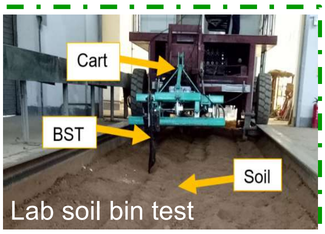


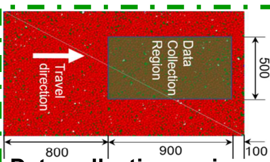


METHOD

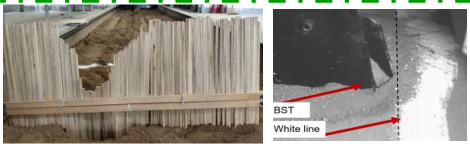
Draught, vertical, and lateral forces and soil disturbance behaviors of the BST with various working speeds were collected from DEM simulations; the collected data were compared and analyzed to investigate the effects of working speed on soil-BST interactions. The DEM model was calibrated and validated using data from subsoiling tests in a laboratory soil bin.







Data collection region in DEM simulations

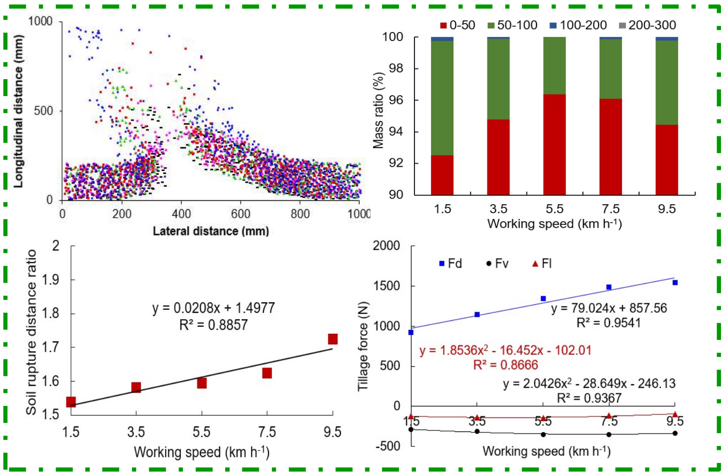


Measurement of soil disturbance area and rupture distance ratio in the lab

RESULTS & CONCLUSIONS

The working speed of the BST had a limited influence on soil lateral disturbance range. A proper increase in working speed could lift more moist soils from deep seed layer and middle layer into shallow seed zone, without significantly affecting the mixing between the deep layer and other layers.

When working speed of the BST increased from 1.5 to 9.5 km/h, it led to a larger draught force, greater soil surface flatness, higher soil rupture distance ratio, and lower soil loosening efficiency. As working speed of the BST increased from 7.5 to 9.5 km/h, soil surface flatness increased rapidly.



Taking into account soil layer mixing, soil loosening efficiency, and soil surface flatness, working speeds below 9.5 km/h were recommended for the BST.

The relative errors between the simulated and measured soil rupture distance ratios and draft forces were 2.97-8.15% and 5.36-13.53% respectively. Average relative error between simulated and measured soil disturbance areas was 7.04%. Above small relative errors indicate the DEM model has a good accuracy and can be used to simulated soil–BST interaction.

FUTURE WORK

The present study primarily concentrated on the interaction between soil and the bending subsoiling tool, and results were restricted to specific soil category under investigation. Future research should delve into the internal mechanisms of bending subsoiling tool - soil interactions in other soil categories and soil conditions with crop residue.