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Development of Profile Meter for Measuring Displacement and Disturbance of Soil by Ridger

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ABSTRACT: A specialized Soil Profile Meter was developed to assess the degree of soil disruption caused by various types of ridgers. Constructed from mild steel, steel, and aluminum composite panel materials, the meter measures 80×100cm in width and height. To calculate the area of soil disruption, three ridgers were simultaneously attached to the tool test setup, integrated into a tool trolley within a soil bin. The tool test setup, connected to the Extended Octagonal Ring Transducer (EORT) with a force limit of 5 KN, measured forces in the horizontal (Fx), vertical (Fy), and moment (My) directions as it was pulled through the tool trolley. Power for the soil processing and tool carriage trolley was provided by a 15-hp electric motor, with different operation speeds achieved by adjusting the motor's rpm through the Human Machine Interface (HMI). In the soil bin, the tool disrupted the soil at depths of 8, 10, 12, 14, and 16 cm. The ridgers used for soil loosening were of tyne, hoe, and shovel types. Some challenges were faced during the measurement of exact ridge height and soil volume after passing the ridgers. So, it was the needful task to design the soil profile meter for measuring the soil profiles. After calibration, the profile meter was positioned across the tilled soil to measure parameters such as width of soil throw, width of cut, ridge-to-ridge distance, height of ridge furrow, and tool width for each ridger operation. The collected data were thoroughly analyzed to establish relationships between the depth of ridger operation and the extent of soil disturbance. Among the ridger types, the hoe type demonstrated the highest soil loosening capacity at all operating depths, followed by the shovel type and the tyne type. Notably, at a fixed width of 40 cm and a speed of 2.5 kmph, the ridger with wings exhibited the greatest soil loosening ability across all depths. The hoe type ridger achieved an estimated transverse soil disturbance area of 82 cm, while the shovel and tyne types recorded 75.5 cm and 69.9 cm, respectively. Conversely, at a working depth of 16 cm, the hoe type ridger again outperformed the others, achieving 84 cm of soil disturbance, with the shovel and tyne types recording 78 cm and 72 cm, respectively.

Keywords: Profilemeter, Width, Depth, Vertisol, Width of Soil Throw, Ridger.

INTRODUCTION

A soil profile meter is a device used to measure the various characteristics of soil at different depths in a soil profile. Soil profile meters are an essential tool for anyone working in agriculture, environmental science, or geology, and can provide valuable information about the soil that would be difficult or impossible to obtain by other means. Determining the displacement of soil or the extent of soil disturbance caused by a tillage tool is crucial when assessing the impact of tillage and various soil parameters on soil disruption. Factors such as tool geometry (width, rake angle) and other parameters like speed, cone index, soil texture, bulk density, porosity, soil moisture, and pH play a significant role in influencing the degree of soil disturbance during tillage operations. As a result, researchers typically prioritize the accurate measurement of the area of soil disruption. Various methods have been employed for this purpose. According to Ale *et al*. (2013); Ademosun *et al.* (2014), the measurement of soil displacement area by tillage tools involved using a meter rule. In their approach, a steel metric rule was placed on the original soil surface level across the trench. The distance measured between the ruler and the slot bottom represented key parameters such as maximum furrow depth to height (after soil cut furrow depth), maximum width of soil disturbance, maximum width of soil throw (using a sweep), ridge-to-ridge distance, height of ridge above the soil surface, and maximum furrow depth to mound height Borselli and Torri (2010).

Hegazy (2013) introduced an innovative approach to measuring soil surface profiles. This technique involves a newly designed soil profile meter, digital imaging equipment, and image tracking and analysis software. The utilization of this modified soil profile meter enables the observation and measurement of alterations in irrigation channels and small ditches, allowing for the quantification of changes at distinct cross sections within soil furrows. The recorded profile heights at various locations provide clear insights into the geometry of furrows and ditches, both before and after the seasonal irrigation process.

Hegazy (2013) emphasized that each type of tillage tool and ditch creation method imparts a unique pattern of roughness and profile on the soil surface. These patterns can be accurately quantified through the application of simple geometric models. Various traditional approaches have been explored for collecting data on soil surface characteristics and analyzing resulting datasets. Among these, pin meters have gained popularity due to their straightforward design. Pin meters consist of either a single probe or a row of probes spaced at predetermined intervals, gliding along the soil surface until their tips make gentle contact. The positions of the pins are then recorded, either electronically or manually by Romkens *et al.* (1986); Wagner and Yiming (1991), and Guler *et al* (1999). It's essential to note, however, that a significant drawback of this technique lies in its potential to disturb the soil surface during data collection in the field. To address this issue, Kornecki *et al.* (2008) developed and tested a portable meter specifically designed for use in typical field conditions. This innovative tool is capable of measuring soil characteristics at depths of up to 500 mm and can be easily adapted for application in larger ditches.

Utilizing Laser technology to measure soil profiles has demonstrated excellent results in laboratory settings. However, its practical application in the field is constrained by factors such as sunlight interference, hidden structures casting shadows, and sensitivity to high temperatures affecting the measurement devices (Pardini, 2003; Darboux and Huang 2003). Moreno *et al.* (2008) embarked on a study to devise a more reliable method for assessing soil surface roughness. A method on shadow analysis, utilizing the direct correlation between soil surface roughness and the shadows produced by soil structures when exposed to consistent sunlight conditions. Their research revealed that shadow analysis produced results strongly correlated with those obtained using pin meters. Notably, this method offered the advantage of significantly reducing the time required for field data collection, typically by a factor of 12 to 20.

Assessing the extent of soil disruption or movement caused by various tillage implements is as vital as determining the draft energy required. Pin-style profile meters have traditionally been the preferred means of gauging soil movement due to these implements. According to Raper (2007), these devices consist of a series of evenly spaced pins that are gently lowered onto the soil surface until they make contact. In the case of ridgers designed to reduce soil compaction and minimize residue disturbance. To determine the width and volume of the displaced soil after each set of tillage experiments, we utilized a portable tillage profiler, as detailed by Raper *et al.* (2004); Raper (2005). The disturbed soil was then manually excavated from the trenched zone in each plot, covering an approximately 1-meter stretch along the tillage path. This procedure facilitated five distinct measurements of the area of the ridged furrow soil disturbed during the tillage event in each plot, often referred to as the trench. Great care was taken to ensure that only soil loosened by tillage was extracted.

Soil disturbance parameters, encompassing lateral soil throw, ridge height, dip and furrow width, cross-sectional area, and depth, play a crucial role in tillage and furrow opener research (Aikins *et al.*, 2018, 2019). These parameters are commonly obtained by comparing soil surface profiles before and after tillage, along with analyzing the cross-sectional profile of the excavated furrow (kojo *et al.*, 2019; Bandalan *et al* 1999; Sakai *et al.* (1983) Barr *et al.*, 2016). The furrow profile provides insights into the actual furrow depth and critical depth (Barr *et al.*, 2016). Typically, these comparisons are visually represented in plots, such as Fig. 1.

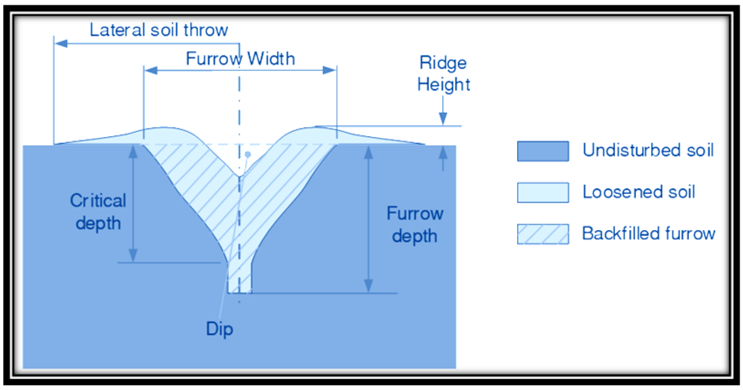

Fig. 1. After passing of ridger, furrow profile from the redrawn from Barr *et al.* (2016).

The most commonly employed techniques for assessing furrow profiles involve the utilization of pin profile meters and laser scanners. Several researchers have relied on manual profile meters for this purpose. These meters are equipped with vertical pins that are vertically displaced to trace either the soil surface profile or the profile of an excavated furrow. However, it's important to note that these manual profile meters typically exhibit relatively low resolution. For instance, the ones employed by featured pin intervals of 1 cm. Furthermore, the use of pinned profile meters carries the potential risk of pins penetrating loose or soft soil, potentially compromising depth measurements.

Given these challenges, the primary objective of this study was to explore the suitability of a portable and cost-effective device designed to measure soil surface and furrow profiles to a maximum depth of 50 cm. The study involved comparing profiles obtained using this device at various depths of tool passage and assessing soil disturbance at different depths. It's worth noting that the designed measurement system is lightweight, portable, and conducive to low-cost field experiments, making it a valuable asset for researchers in this field.

MATERAIL AND METHODS

Test site: A study took place within an indoor soil bin at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, JNKVV, Jabalpur (M.P.). The location is positioned at latitude 23°09' N, longitude 79°05' E, with an elevation of 411.78 meters above mean sea level.

Experimental tillage tools: Testing of three different types of the ridgers (a) shovel type, (b) hoe type, and (c) tyne type shown in Plate.1 was done under the controlled experimental conditions in a soil bin that was filled with Vertisol (USDA classification).

Soil bin facility: The trials took place within an indoor soil bin facility. The length of the stationary soil bin was 20.0 m, and it had a width of 2.37 m and a height of 1.02 m. On the top of the longitudinally opposite sides of the soil bin walls, 28 pillars (14 on opposite sides) were placed for mounting the rail. The soil processing trolley and test trolley were to be run on the rail. The soil processing trolley was attached with a rotavator for soil bed preparation, a leveller for levelling the soil bed, a roller compactor for maintaining soil compactness, and a water tank with nozzles for maintaining the moisture content of the soil. Test trolley for testing of the tools was associated with provision for testing of both active and passive type tillage tools. Cone penetrometer with force (type U9C/5 kN) and displacement transducer (Type WA/200 mm) for measuring the soil compaction.

Profile Meter Design Considerations:

- The design of the profilometer used for measuring soil disturbance in the study took into account the following considerations:
- Weight of material: Opting for lightweight materials ensures the portability of the profilometer.
- Height and Width of equipment: The equipment's height and width were configured to enable measurements of soil disturbance to depths and widths of 50 and 75 cm, respectively.
- Stability of equipment: Ensuring stability was a key factor, allowing the equipment to stand independently during its operation.
- Smoothness of the equipment surface: The surface of the equipment was designed to be smooth, facilitating easy application and removal of graph paper.

Profile Meter Components Design: The design of the width of the profile meter, intended for measuring the width of soil failure, drew inspiration from Godwin's work in 2007. In his specifications, he indicated that the width of soil disturbance should be 1.5 times the depth of tool operation for narrow or simple tines and 2.0 times the depth of tool operation for wide or winged tines. Consequently, for a ridger with a width of 20-40 cm operated at a depth of 8-50 cm, the total width of soil disturbance was calculated as 1.5 times 50, resulting in 75 cm (750 mm). The estimated width of soil disturbance for the profile meter was set at 80 cm.

The Profile Meter had the following dimensions:

- Fabrication: 50×50×3mm mild steel square pipe was used to construct the profile meter.
- Ridge Profile: 10mm diameter round steel pipes were employed for creating the ridge profile.
- Structure: Two 80 cm square pipes for width and a 100 cm height square pipe were welded to form a square frame, with the middle of the round pipes secured using close caps.
- Back Side: A white board with graph paper was utilized on the back side for drawing the ridge profile.

Plate 1. Soil Bin and Tillage Tool.

Profile Meter Description: The profile meter for measuring soil disturbance consisted of a mild steel frame and steel round pipes for graph measurement. The equipment's total height was 100cm, and it had a total width of 80cm. A white board was securely affixed to one side of the frame, with graph paper pasted onto the board. At the base of the frame, 40 holes were drilled at equal distances. Forty 10mm diameter round steel pipes were inserted into these holes, each capped at both ends with rounded shape caps. The caps on the upper side had a larger outer diameter than the pipes.

These horizontal pipes traversed through each of the vertical round pipes up to the cap end. The vertical round pipes were guided at the front by two horizontal square pipes placed across the equipment at two points. These square pipes served to protect the vertical steel pipes from slipping off the board during operation. When placed across a depressed soil and the top horizontal square pipe is removed, the vertical steel pipes may slide downward and settle according to the disturbed soil's geometry. The tips of the vertical round pipes could be easily traced on the graph paper affixed to the board.

Profile Meter Calibration: To ensure the accuracy of soil disturbance measurements with the constructed profile meter, a meticulous calibration process was conducted. This calibration occurred within the soil bin at the Department of Farm Machinery and Power Engineering. A tillage tool was employed intentionally to disturb the soil to varying depths and widths.

For a specific point, a steel rule was used to measure both the depth and width of the disturbance, aiding in estimating the disturbance area. Subsequently, the profile meter was placed across the disturbed soil area. The horizontal square pipe supporting the vertical round pipes was delicately removed, allowing the steel round pipes to descend naturally and adapt to the soil disturbance's shape. The tips of these rods were accurately traced onto graph paper using a marker.

The area on the graph paper was then calculated in square centimeters based on the squares beneath the reference line, following the method outlined by Kumar and Thakur (2005). Additionally, the disturbance's depth and width were estimated on the paper. These estimated values were then compared to those obtained using the steel rule as a reference. This entire process was repeated five times, adjusting the graph paper as necessary on the board until the areas estimated by the profile meter and the steel rule showed minimal differences.

Profile Meter Testing: The profile meter underwent testing at the indoor soil bin facility within the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, JNKVV, Jabalpur (M.P.). To assess the area of soil disruption, three ridgers (shovel type, hoe type, and tine type ridgers) were concurrently attached to the tool carrier and drawn through the soil bin to loosen the soil at widths of 20, 30, and 40 cm and depths of operation at 8, 12, and 16 cm. Soil disturbance was measured during the operational phase in the soil bin.

Adjustable wings, secured with nut bolts and replaceable, were attached for the operation. The profile meter was operated at speeds ranging from 1.5 to 2.5 kmph at different depths. Subsequently, the profile meter was employed to measure the area of soil loosened by each ridger. Measurements were taken for each depth of operation, and their mean values were recorded. The data generated underwent statistical analysis to establish relationships between ridger types, depth of operation, and soil disturbance, presented in the form of graphs.

(A) Tyne type ridger (B) Hoe type ridger (C) Shovel type ridger

Plate 2: Testing of the ridgers at maximum working depth and width of cut

RESULTS AND DISCUSSION

Calibration of Profile meter: Fig. 2 shows the graph for the calibration of profile meter.

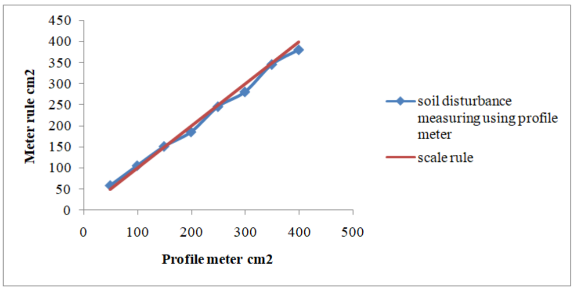

Fig. 2. Soil disturbance measured using meter rule and profile meter.

Soil Transverse Width of Ridgers: Plate 2 illustrates the estimated soil disturbance, as measured by the profile meter, caused by various ridgers operating at different depths. In Fig. 3, with the tool carrier operating at a fixed width of 40 cm and a speed of 2.5 kmph, hoe type ridgers exhibited the highest soil loosening capacity at all depths, followed by shovel and tyne type ridgers, respectively. For instance, at a working depth of 12 cm, the hoe type ridger achieved an estimated transverse soil disturbance area of 82 cm, while the shovel and tyne type ridgers recorded 75.5 and 69.9, respectively. Similarly, at the highest working depth of 16 cm, the hoe type ridger led with 84 cm, followed by the shovel and tyne type ridgers with 78 and 72, respectively.

The considerable difference in the area of soil loosened by the hoe type ridger compared to the shovel and tyne types highlights the significance of increased width and depth in ridgers. It is evident that as the forward speed and width of ridge wings increase with a rise in depth, there is a corresponding increase in soil transverse width and soil loosening.

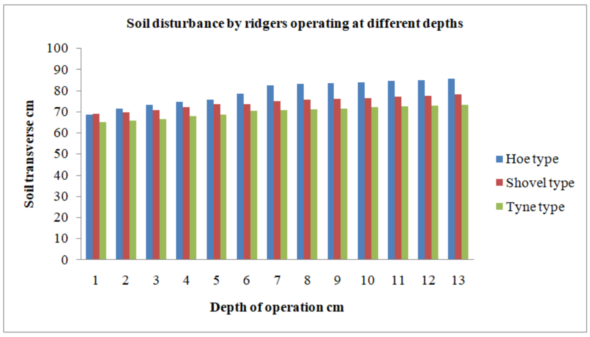

Fig. 3. Soil disturbance by ridgers operating at different depths.

CONCLUSIONS

The research work yields the following conclusions:

— A profile meter was successfully designed, fabricated, and tested during the operation of ridgers in the indoor soil bin facility.

— The profile meter demonstrated superior ease and accuracy in soil disturbance measurement compared to the traditional use of a meter rule.

— At a speed of 2.5 kmph and with a fixed width of 40 cm for ridger wings, the hoe type ridger exhibited the highest soil loosening ability at all depths, with an estimated transverse soil disturbance area of 82 cm. In comparison, the shovel and tyne type ridgers recorded 75.5 and 69.9, respectively. At the highest working depth of 16 cm, the hoe type ridger maintained its lead with 84 cm, followed by the shovel and tyne type ridgers with 78 and 72, respectively.

— The profile meter consistently provided more convenient and accurate results in soil disturbance measurement than the conventional use of a meter rule.

FUTURE SCOPE

Future devices might become more portable, allowing field scientists and agricultural experts to carry out on-the-go analysis. Profilometers might contribute to breakthroughs in our understanding of soil behaviour, composition, and its interaction with various elements.

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