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Measuring root system stiffness in maize or sorghum

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We use this protocol and it's working

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Abstract

Plant mechanical failure has been evaluated with proxy measures that quantify root failure strength. However, understanding the force-displacement rate to reach that failure strength is currently a gap in the field. The force-displacement rate is called the root system stiffness. Here, we outline the steps necessary measuring root system stiffness in maize or sorghum using a new tool developed by our lab called SMURF (Sorghum & Maize Under Rotational Force).

Guidelines

- **Plant Material:**

Plant maize or sorghum seed under standard planting procedures. No specific field conditions are required. Maintain research fields.

> **Note**
>
> It is important to remove weeds and debris around the base of plant to limit non-plant forces being recording.

> **Note**
>
> It is suggested that plants are not tested before the V8 stage.

- **Device:**

A device, called SMURF (**S**orghum and **M**aize **U**nder **R**otational **F**orce), was designed to non-destructively measure the root system stiffness of large grain root systems (Figure 1A). The SMURF applies rotational displacements and measures a force. Below we outline the components of the SMURF as a general overview of the device.

1. The SMURF consists of a physical body, electronics, powertrain, sensors, and software **(Figure 1)**.

- The physical body consists of (**Figure 1A)**:

1. A 3D-printed case housing the electronics and powertrain **(Figure 1A-1)**
2. A battery pack **(Figure 1A-2)**
3. A set of arms with straps to attach the device to the plant **(Figure 1A-3)**
4. A sensor housing case for the load cell **(Figure 1A-4)**
5. A rotational foot for device grounding **(Figure 1A-5)**

- The internal electronics are run via an Arduino microcontroller connecting a motor driver, load cell amplifier, and Bluetooth module **(Figure 1B)**.

- The powertrain consists of:

1. A brushed DC motor
2. A lead screw
3. A battery

- A 10 kg load cell (sensor)

- A custom-built iPad application controls the device **(Video 1)**

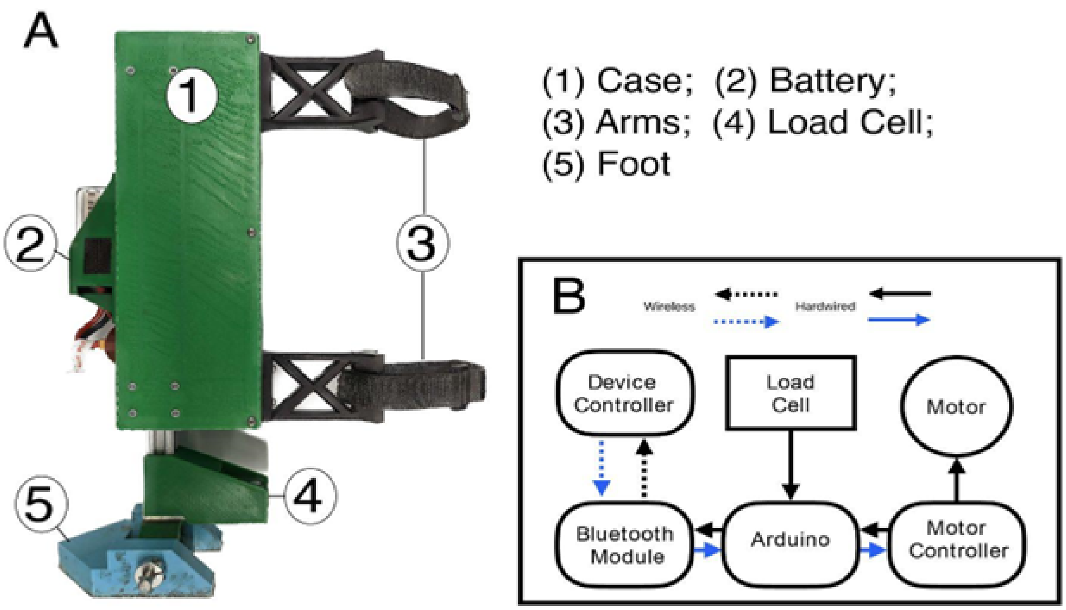

Figure 1. Overview of SMURF device. (A) The physical body is composed of (1) a 3D-printed case housing the electronics and powertrain, (2) a battery pack, (3) a set of arms with straps to attach the device to the plant and limit stalk bending, (4) a sensor housing case for the 10 kg load cell, and (5) a rotational foot for device grounding. (B) The internal electronics, located within the 3D-printed case, are run via an Arduino microcontroller that connects a motor driver, load cell amplifier, and Bluetooth module. Dotted lines indicate a wireless connection, whereas solid lines indicate a hardwired connection between components.

Video 1: Custom-built iPad application controls the device

Before Operating the SMURF:

1 Open the Device Controller iPad application (Video 1).

2 Hold the SMURF horizontally and power on.

3 Calibrate the load cell in the absence of a load.

4 Enter Research ID (e.g. researcher name/initials/identifier) in iPad application (Video 1).

5 Click button: “Save Researcher ID” (Video 1).

6 Click button: “Go to Testing Screen” (Video 1).

> **Note**
>
> Once this is clicked, a pop-up box will prompt connection to the SMURF device via Bluetooth.

7 Click button: “Fully Retract Foot”. This will re-home the device (Video 1).

Operating the SMURF:

8 Attach the device with the two arms as low as possible on the plant while avoiding brace roots.

> **Note**
>
> The straps should be tightly secured to prevent slippage.

9 Enter Plant ID into the text box (Video 1).

10 Select appropriate Test Type (Video 1).

Note

Test Type is an arbitrary, user-defined designation of A through F, which adds flexibility for the user to define different experiments within the same testing set.

11 Click button: “Get Initial Height” (Video 1)

Note

This instructs the device to lower the foot to the ground until the device weight is read on the load cell, which is the “tare” step of the measurement device.

12 Click button: “Small Flex Test” or “Large Flex Test” to start the testing cycle (Video 1)

- A Small Flex Test should be used for any small or mutant plants, whereas a Large Flex Test is the default for all healthy plants.

Note

The device should not be touched during the testing cycle to limit reading and recording external, non-plant forces. During the testing cycle, the lead screw extends 10.5 mm for a Small Flex Test or 15.8 mm for a Large Flex Test.

13 Click button: “Accept Results” or “Reject Results” (Video 1)

- “Accept Results” prompts the data directory to save the data.
- “Reject Results” prompts the device to go back to the original testing screen.

14 Click button: “Move to Next Plant,” which will fully retract the foot and make the device ready for the next testing cycle (Video 1)

Note

This process is repeated for each plant.