Agriculture nets permeability test bench

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ABSTRACT

The agriculture nets permeability test bench is a system to run permeability test on wide variety of materials quickly and accurately. By adjusting the gradient or the flow rate across the sample, the system can measure permeability of agriculture nets while simulating the rain-falls of varying intensities. The test bench includes a linear actuator, centrifugal pump, flow sensors, flow regulators, HMI display and electronic controls. Flow rates can be set to any value between 0.6 l/min to 15 l/min. Once the system is setup the test can be run unattended in a fully automated mode.

Design considerations for ARTIFICIAL RAINFALL CREATION:

In order to evaluate the performance of agriculture textile the physical characteristics of natural rain should be reproduced as accurately as possible. The artificial rain imitated closest to the natural rain will help the user to match the technical textile specifications at the laboratory scale to its performance in the real field conditions. This also is important to perform a reliable and repeatable measurement, which is useful as a standard to compare performance of different textiles. In the real field situation, the natural rain varies with the fall velocity, rain fall intensity and wind. Thus, in order to have a comparative performance evaluation and calibration of the system, open field tests are also proposed to be performed.

All the physical characteristics of natural rain should be reproduced as accurately as possible. The two main characteristics targeted to achieve are:

- Drop size and distribution variation: Raindrops vary from the minute droplets in mist up to a maximum of 6 or 7 mm diameter. The median drop diameter by volume lies between 2 and 3 mm and varies with intensity. This distribution varies from cyclonic rain having small and average size drops to high-intensity tropical thunderstorms having higher proportion of large drops.

- Rainfall intensity or rate of rainfall: This usually varies rapidly in natural rainfall, but is not important to integrate in rainfall simulators the ability to change intensity during a test. It is usual to choose and design for a single value of intensity, for example 25 mm/h to simulate temperate rainfall, or 75 mm/h for tropical or semi-arid rainfall per square meter application area.

Table 1: Rainfall characteristics chart

Benchmark	**Rainfall type**		
	Drizzle rainfall	**Showers rainfall**	**Thunderstorm rainfall**
Rainfall rate	< 20 mm/hr	20 mm/hr – 70 mm/hr	70 mm/hr – 280 mm/hr
Rain period	> 20 min	10 min – 25 min	4 min – 7 min
Nature events	Slow and lengthy	Intermediate, without noise and lightening	Sudden with noise and intermediate lightening

ARTIFICIAL RAINFALL CREATION

The principle of drops forming and dropping from the tip of tubes connected to a water supply is used to make artificial rainfall. The size of drop is related to the size of the tubing and the drip nozzles installed. It offers advantages that the size of the drops and their fall velocity are constant and also the distribution of rainfall across the test plot is uniform.

The disadvantages are that unless the device is raised up very high, the drops strike the test plot at a velocity much lower than the terminal velocity of falling rain, and therefore the values of kinetic energy are also low. A large drop of 5 mm diameter needs a height of fall of about 12 meters to reach terminal velocity and this is difficult to achieve in field conditions. To some extent this is be compensated by using larger drops than in natural rainfall, and by using water pressure for spraying nozzles by gravity or by pumping. For this reason, to attain higher pressure in our system centrifugal pump is used.

In rainfall studies, relevant knowledge of the corresponding natural rainfall properties like rainfall intensity and rainfall uniformity are crucial. The real-time measurement of total rainfall and rain intensity is done by analog flow sensors installed in the water supply line. A tipping bucket rain gauge system is used to measure the rainfall uniformity over the application area and the rain drop velocity from nozzles.

TEST PROCEDURE

Step 1: Setting test parameters

The test is performed at different inclinations of fabric ranging from 0 – 30°. Desired fabric inclination is set by control knob which regulates potentiometer feedback linear actuator **(Figure 1)** assisted tray elevation system. The user interactive display outputs the elevation (in angles) the desired value (setpoint, SP) and the current measured value (process variable, PV).

After setting the correct inclination of the fabric, approximately 25 liters of water is introduced into the collection tank volume. The water is then circulated in the system through the pump. The desired flow rate is first coarsely set by the gate valve situated at the recirculation pipe and fine adjustments are made by the second gate valve situated preceding the flow meter. The first turbine flow meter **(Figure 2)** measures the inlet flow rate (l/min) and volume (l) and the values are displayed on the test parameter setup screen.

The test volume which controls the test-run period is set by SET VOLUME section of touch screen. This stops the circulation pump automatically once the set volume is reached.

Step 2: Running the test

After all of the test parameters (inclination, rain-fall application rate, test volume) are configured, operator waits for the system to stabilize to attain steady state condition. Once achieved the system is changed from MANUAL to AUTOMATIC mode using the Selector Switch of the control panel. The measurement is then restarted using RESET switch, which sets the time t=0 for measurement. The display screen is switched to the second page. At this stage the Normally Open Solenoid Valve **(Figure 3)** installed to collect the water in measuring tank closes and it remains closed during the duration of the test. At this stage the water passing through the net starts collecting in the measuring tank. Once the set volume is reached automatically the water pump stops and the Solenoid Valve opens. A non-return valve is installed in the pumping line as a backflow prevention The collected water then starts draining from measuring tank to the collection tank and through the second flow meter starts measuring the outlet water volume (l). Once the whole water is drained in the and the measuring tank is empty, the system displays the final permeability of the net.




USER INTERACTIVE TEST DISPLAY

For the user interactive display Nextion Human Machine Interface(HMI) 2.4” Inch TFT is used. Nextion HMI display connects to the peripheral Microcontroller Unit (MCU) Arduino Nano via TTL Serial (5V, TX, RX, GND). **(Figure 5)**

Figure 5 Nextion HMI 2.4” Intelligent HMI Display

The **first page** of the developed Graphical User Interface GUI display screen shows the following test SETUP parameters **(Figure 1)**:

A. Bench Inclination – (1) Set Angle (°), (2) Now Angle (°)
B. Rain fall application rate - (1) Inlet Water rate (l/min), (2) Total Outlet Water (l)
C. Test period - Set Volume (l)

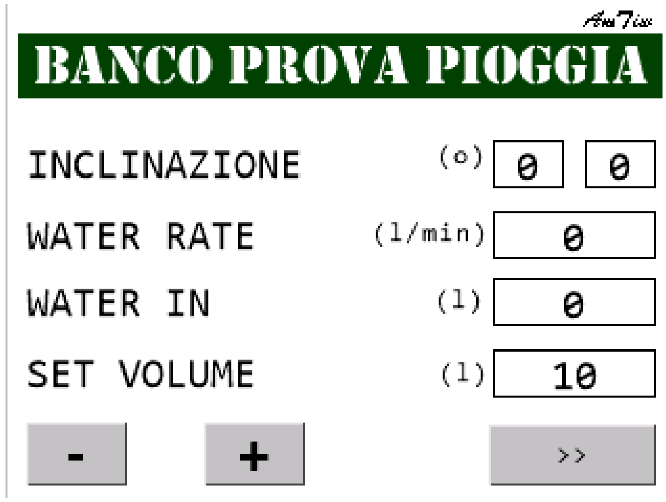

Figure 2 HMI DISPLAY - Page 1 – TEST SETUP SCREEN

The **second page** of display screen show the following test RESULTS parameters (**Figure 2**):

A. Simulated rain parameter – (1) Rain Intensity (mm/hr), (2) Total Rain (mm);
B. Test running parameters - (1) Total Inlet Water (l), (2) Inlet Water rate (l/min), (3) Total Outlet Water (l);
C. Test result – Net Permeability (%).

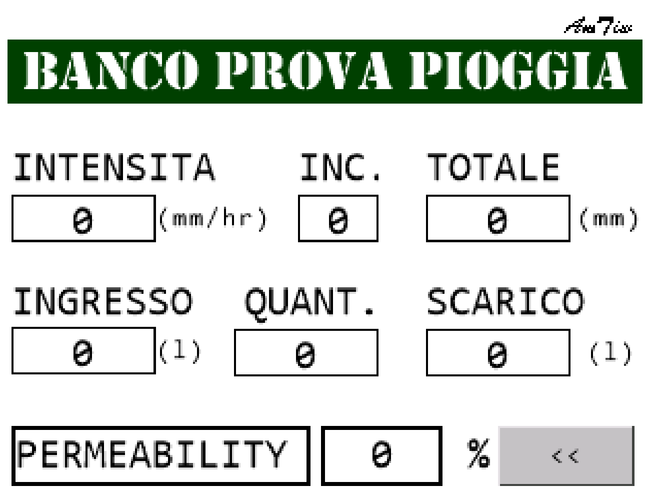

Figure 3 HMI DISPLAY - Page 2 – TEST RESULTS SCREEN

RAINFALL UNIFORMITY TEST

The results of rainfall uniformity and rainfall intensity measured with Tipping Bucket rain gauge system **(Figure 3)** is represented by a heatmap in **Figure 4**. 27 representative measurements were taken at 9 locations to evaluate these parameters. When the measurement is set at flow rate of 1 l/min, the average flow rate from one nozzle was 0.023 l/min, which averages for 45 working nozzles a total velocity of 1.013 l/min. These validates the results, and confirms the uniformity of our artificial rainfall creation system.

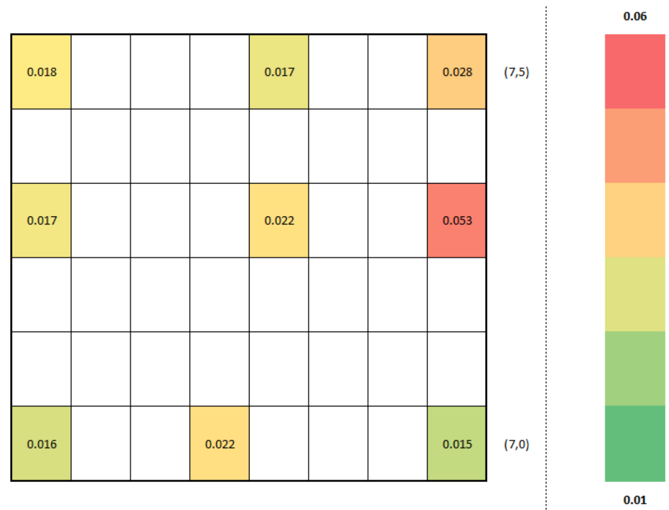

Figure 3 Tipping Bucket rain gauge system

Figure 4 Velocity map of drip nozzles rain fall rate (l/min)

Water Permeability Calculation

The water permeability of a textile is a measure of the property of the **textile** to transmit water across it. Water permeability is defined in this case as the amount of water passing across a known area. Based on empirical observation the formula for water permeability is developed and modeled as:

$$\text{Permeability (\%)} = 1 - \frac{Vol_{in}}{Vol_{out}}$$

where, Vol_{in} = Total Inlet Volume

Vol_{out} = Total Oulet Volume

To evaluate the performance of the system plastic film which is completely impermeable (permeability = 0) is used. This also serves as the control test for our system. 9 different measurements were performed and the average values with their standard deviation are given in Figure 4. The least SD is achieved at the test volume of 15 l which supports the fact that increasing the test time reduces the random errors. For 15 l of test volume the permeability of system is -0.33 with sd of ± 2.1.

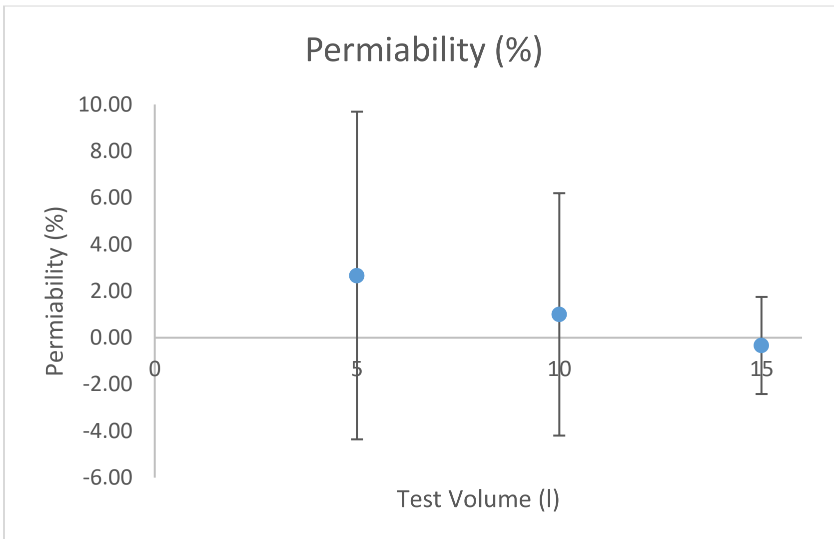

Figure 4 Permeability measurements on plastic film using test bench