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DESIGN, PRINCIPLE AND USES OF TENSIOMETERS

BY

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ABSTRACT

Two types of tensiometers were developed locally i.e., one mercury manometer type and the other Bourdon gauge type. These tensiometers were used in various research studies conducted in lysimeters as well as in the field to measure soil water potential at various depths in the root zone. The crops trialed were wheat, maize, sugarcane, sunflower, berseem, sorghum etc.

It was felt that mercury manometer type tensiometers were more sensitive but difficult to install and handle in the field; while Bourdon gauge type tensiometers were easy to install and manage in the field.

Tensiometer readings were used to decide time for irrigation and its amount. It also helped to predict crop irrigation needs well in advance. The data generated from the tensiometers also helped to examine water extraction patterns of various crops under different stages of crop growth and irrigation strategies.

In this paper various components of the tensiometer, uses, benefits and limitations have also been discussed.

INTRODUCTION

Tensiometers were originally designed and developed in the 1920's and 1930's (Richards, 1949). Due to their ability to measure directly energy status of soil water, they have been used extensively all over the world to determine soil water status and water availability to crops.

In Pakistan use of tensiometer is not very extensive, only a few research organizations are using this instrument in a very limited scale. The root cause of this is either high cost of imported tensiometers or lack of skill for efficient use of tensiometers.

The design of tensiometers have changed a little over the years. The modifications made have improved reliability, simplified observations and easy handling of the instrument.

The purpose of this paper, therefore, is not only to share personal experience for local development of tensiometers but also to share other technical aspects in handling, operating and data evaluation of the tensiometers.

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DESIGN AND PRINCIPLE OF TENSIOMETER

A tensiometer basically consists of four essential parts; the tensiometer tip, the stem or body barrel (tubing), the fluid filled in the tensiometer in which soil suction potential is developed in equilibrium with soil water potential, and a device to measure the negative pressure of the fluid in the tubing. The tensiometer tip is generally made of porous ceramic material, known as ceramic cup (Cassell and Klute 1986), and the fluid most commonly used is water. The other two components i.e., tensiometer stem and pressure measuring devices have varied in design and material depending upon the materials and technology available, the working conditions under which measurements were to be made and frequency, accuracy and sensitivity requirements of the observations. (Richards 1949; Marthaler 1983; Kassell and Klute 1986).

Two types of tensiometers were developed locally i.e., one mercury manometer type and the other Bourdon gauge type. The two designs are briefly described below:

Mercury Manometer Tensiometer

A schematic sketch of locally developed soil moisture tensiometer is shown in Fig. 1. It consists of a glass U-tube (3mm dia) manometer fixed on a graduated board and filled with mercury upto about 40cm height a ceramic cup cemented on one end of a PVC tube while the other end of the PVC tube is connected with the one arm of mercury manometer through 5mm nylon tubing.

Before installation the porous cup is properly saturated with air free water and the whole tube from ceramic cup to mercury level in one arm is completely filled with air free water.

Bourdon Gauge Tensiometer

A schematic design of Bourdon gauge tensiometer is shown in Fig.2. It mainly consists of a Bourdon gauge, ceramic cup and a stem (body). The whole inner part including pores of the ceramic cup are properly filled with air free water.

PROCEDURE FOR SATURATING THE POROUS CUP

Each tensiometer should be out gased and its porous cup be properly saturated before its installation in the field. One of the simplest procedure is described below:

Remove the cap of the tensiometer and fill it with air free water. Air free water can be obtained by boiling water for 10-15 minutes. Water should be allowed to cool before its filling in the tensiometer. After filling the tensiometer, keep it vertically for some time till water oozes out from the pores of the cup and makes big drops to escape down from the cup. The water level inside the tensiometer will fall down. Refill the tensiometer with water and replace the cap tightly. After that, keep the tensiometer in open air so that water may evaporate from the surface of the tensiometer cup. Keep the tensiometer in vertical position.

After some time the reading on the gauge will start rising. When it reaches 50-60 cb, many air bubbles will appear inside the tensiometer. Tap the wall of the tensiometer stem gently so that all air bubbles accumulate at the top (near tensiometer cap). Remove the cap and fill it with air free water. Repeat the same procedure for another time. Now tensiometer is ready for installation in the field.

For installation in the field, select a representative spot and make a hole with a proper sized auger. The hole should be 2 to 3 inches deeper than required depth. Pour some water and loose soil in the hole. Then push the tensiometer in position. Also tighten the soil around tensiometer so that water may not flow along the pipe of the tensiometer. Remove cap while pushing the tensiometer in soil to save gauge from suspected high pressure which generally develops while pushing the tensiometer in the tight hole.

After installing the tensiometer, refill it with water and cap it tightly. The reading will start increasing after some time. Tensiometer reading for initial some time is not representative because of added water in the hole surrounding tensiometer cup . This water will either move towards the surrounding soil or will be consumed by the crop through roots. Then tensiometer readings will become representative. In order to avoid error, the tensiometers should be installed before applying first irrigation.

The same procedure can also be adopted for mercury tensiometers. In this case whole of the tube from ceramic cup to mercury level in one arm is completely filled with air free water.

MAINTENANCE AND DATA COLLECTION

During operation, air often diffuses into tensiometer through tensiometer cup which accumulates at the top part of the tensiometer. The air entry is more when the soil moisture tension is high. The air should be removed by refilling with air free water when the volume of air inside the tube becomes 2 to 3 c.c.

The tensiometers having vacuum Bourdon gauges give directly soil moisture tension in centibars. Reading from the manometer type of tensiometers (Fig. 1) need conversion. The following relationship can be used to convert mercury manometer readings into centibars:

$$M\ (cb) = 1.33 \qquad (h\text{-}x.h/pm) \qquad ....I$$

Where M(cb) = Matric potential equivalent to soil moisture tension expressed in centibars.
h = Difference in the heights of mercury levels in the manometer.
x = Height of water column from the middle of cup to lower level of mercury in the u-tube.
pm = Density of mercury.

USES OF TENSIOMETERS

Tensiometers are generally used to monitor soil moisture tension in the root zone. The data generated help to predict time and amount of irrigation needed to replanish field capacity in the root zone.

A typical graph showing variation in soil moisture tension during growth period of a crop is shown in Fig. 3. It is clear from the graph that crop water requirements are different at different stages of crop growth. If irrigation is applied according to needs of crop, then crop performance will improve considerably. This way also save a lot of precious surface irrigation water especially under shallow water table conditions.

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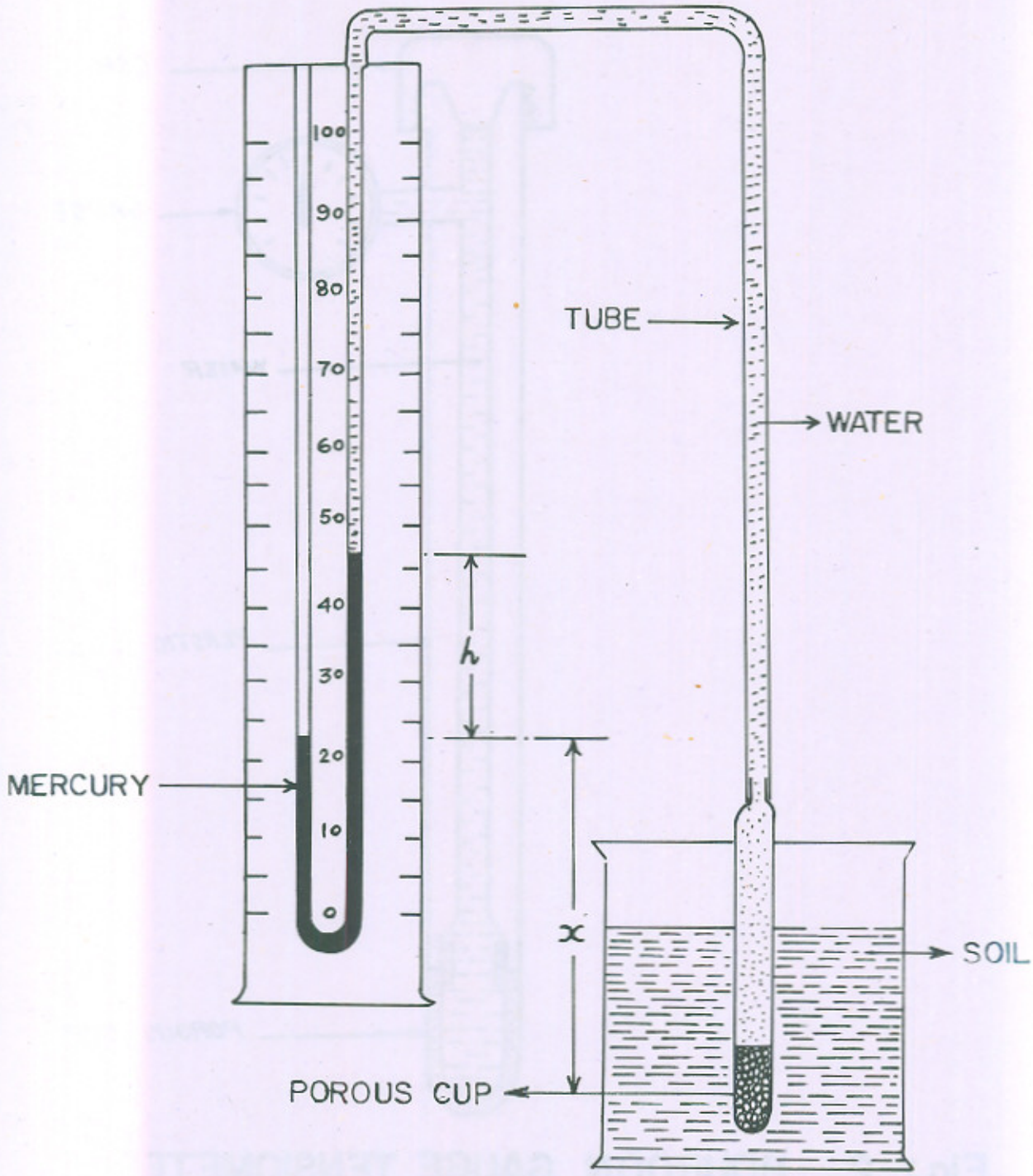


Fig:- I MERCURY MANOMETER TENSIOMETER.

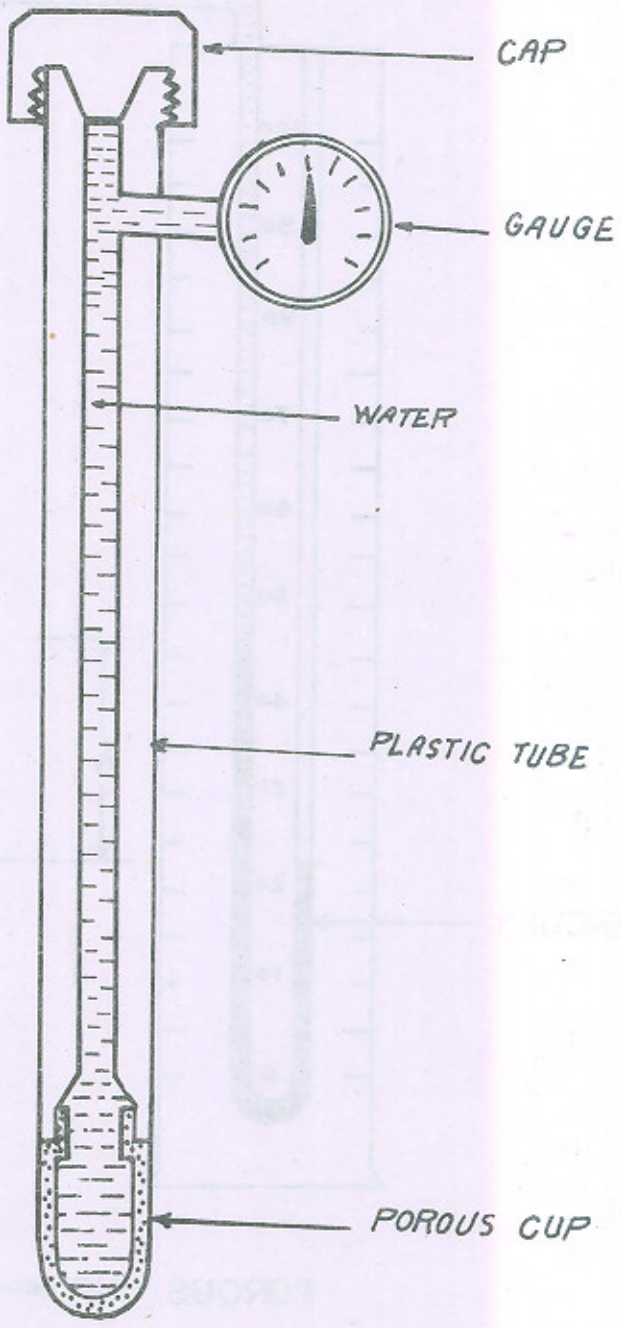


Fig:- 2 BOURDON GAUGE TENSIOMETER

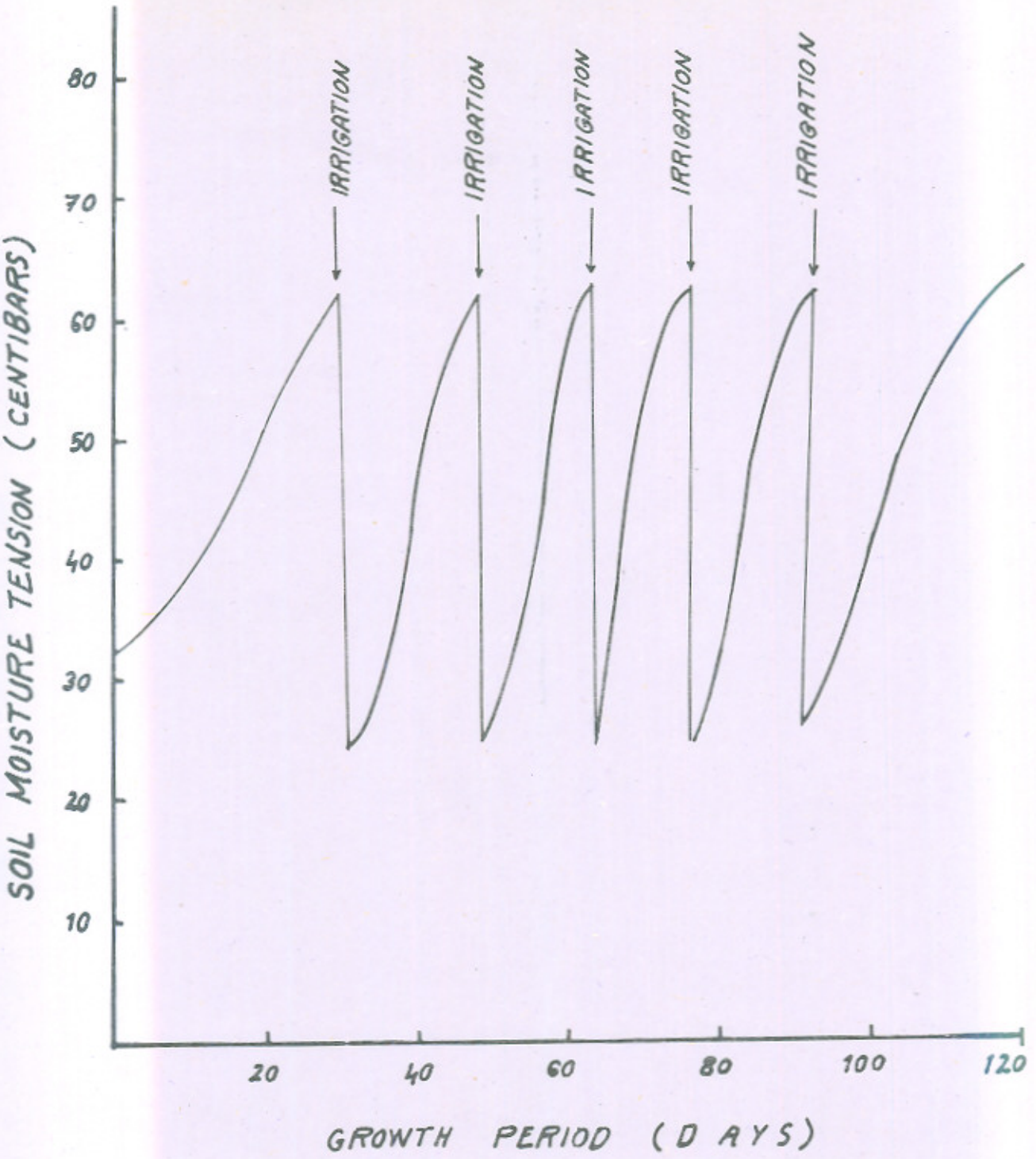


Fig- 3 VARIATION IN SOIL MOISTURE TENSION DURING GROWTH PERIOD OF A CROP MEASURED WITH A TENSIOMETER

