DEVELOPMENT OF A TENSIO-EMITTER

- A TENSION CONTROLLED EMITTER

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TAVANUR – 679 573, MALAPPURAM

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PROJECT REPORT

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IN

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679 573, MALAPPURAM

KERALA, INDIA

2007

DECLARATION

We hereby declare that this project entitled **“Development of a Tensio-emitter – A Tension Controlled Emitter”** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other university or society.

Place: Tavanur

Anu Subramanian K.

Date:

Della Thomas

Sameera Abdul Salam

CERTIFICATE

Certified that this project report entitled “**Development of a Tensio-emitter – A Tension Controlled Emitter”**is a record of project work done jointly by **Anu Subramanian K., Della Thomas and Sameera Abdul Salam** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to them.

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Anu Subramanian K.

Della Thomas

Sameera Abdul Salam

Dedicated

To

Our Loving

Parents

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SYMBOLS AND ABREVIATIONS

C - conductance
cb - centibar
cm - centimetre
$C*$ - conductance of the ceramic cup
Dept - department
dq/dt - flux of water across the cup
et al - and others
Fig - figure
G. I - galvanized iron
K - hydraulic conductivity
K. C. A. E. T -Kelappaji College of Agricultural Engineering and Technology
kPa - kilo Pascal
/ - per
m - metre
min - minutes
r - cup radius
S - gauge sensitivity

sec - second

T_R - instrument response time

V - volts

ψ_S - the suction just outside the cup in the soil-water system

ψ_T - the suction of water in the tensiometer

Introduction

INTRODUCTION

Water stress and excess water affects yield and quality of the produce. Over application of irrigation water decreases water use efficiency and increases nutrient leaching. Low pressure irrigation methods such as drip irrigation systems have become wide spread in high value horticultural crops. It is important to know how much irrigation is to be done.

1.1 TENSIOMETER

Tensiometers are instruments that are used to measure the energy status (or potential) of soil water. They continuously monitor soil water status, which is useful for practical irrigation scheduling, and are extensively used on high-value cash crops where low water tension is desirable. The measurement of water potential is very useful because it is directly related to the ability of plants to extract water from the soil. Irrigators often use tensiometers for irrigation scheduling because they provide direct measurements of soil moisture status and they are easily managed. In addition, tensiometers can be used to automate the control of irrigation water applications when the soil water potential decreases to a predetermined critical value.

Tensiometer was invented by Burton E. Livingston in 1908. It measures the matric or capillary potential and provides a direct measurement of the tenacity with which water is held by soils. They can also be used to estimate the soil moisture content.

1.2 TENSIOMETER COMPONENTS

A tensiometer consists of a thin-walled porous cup, connected through a rigid body tube to a vacuum gauge, with all components filled with de-aired water. The porous cup is normally constructed of ceramic because of its structural strength as well as permeability to water flow. The body tube is normally transparent so that water within the tensiometer can easily be seen. A Bourdon tube vacuum gauge is commonly used for water potential measurements. The vacuum gauge can be equipped with a magnetic switch for automatic irrigation control. A mercury manometer can also be used for greater accuracy, or a pressure transducer can be used to automatically and continuously record tensiometer readings. The figure illustrates the components of one model of a commercially available tensiometer using a vacuum gauge.

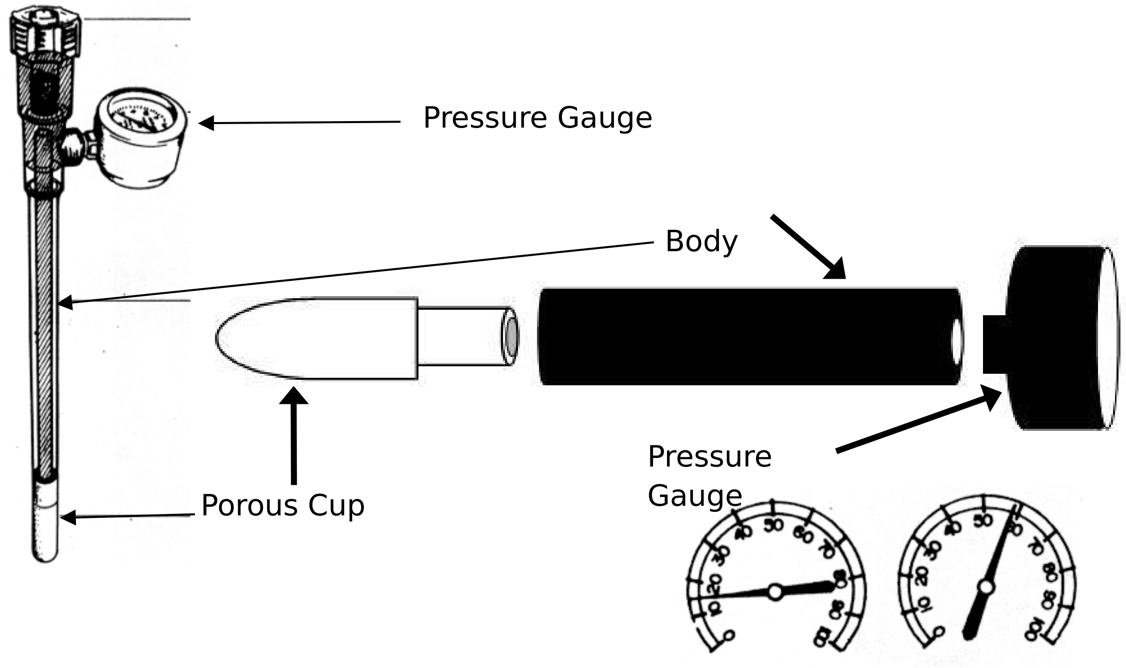

Fig. 1- Components of tensiometer

The porous cup is fitted to the inside tube and is then connected to the vacuum gauge or manometer. The system is filled with boiled or distilled water to remove air. The inside tube comes at the top through which water is filled into the system and the opening is closed air tight by a rubber cork taking care that no air bubble or air space remains inside the system. The porous cup is placed into the soil at a desired depth and the vacuum gauge or manometer is kept above the ground to facilitate a constant reading of tension. Tensiometer cost depends on its length, or the depth at which it will be installed.

1.2.1 PRINCIPLE OF OPERATION

Tensiometers are placed in the field with the ceramic cup firmly in contact with the soil in the plant root zone. The ceramic cup is porous so that water can move through it to equilibrate with the soil water. A partial vacuum is created as water moves from the sealed tensiometer tube. The vacuum causes a reading on the vacuum gauge which is a direct indication of the attractive forces between the water and soil particles. This reading is a measure of energy that would need to be exerted by the plant to extract water from the soil.

Because the porous ceramic cup is permeable to both water and dissolved salts, tensiometers do not record the water potential due to dissolved salts (osmotic potential). The actual total potential that plants would need to overcome to extract water from soils includes the osmotic potential. If soils are saline, or if poor quality irrigation water is being used, the osmotic potential will be a large portion of the total potential. In those cases, osmotic potential should also be measured using soil salinity sensors. As the soil dries, water potential decreases (tension increases) and the tensiometer vacuum gauge reading increases. Conversely, an increase in soil water content (from irrigation or rainfall) decreases tension and lowers the vacuum gauge reading. In this way, a tensiometer continuously records fluctuations in soil water potential under field conditions.

Rapid and accurate tensiometer response will occur only if air does not enter the water column. Air expands and contracts with changes in pressure and temperature, thus causing inaccurate tensiometer readings. Even if instruments do not have leaks, dissolved air enters with water flow through the ceramic cup during normal operation of the instrument. When a significant amount of air enters the instrument, it must be expelled and the tensiometer should be refilled with water before it will operate reliably again.

1.2.2 UNITS OF MEASUREMENT

The tensiometer measures water potential or tension. Water potential is commonly measured in units of bars (and centibars in the English system of measurement) or kilopascals (in metric units). One bar is approximately equal to one atmosphere of pressure. One centibar is equal to one kilopascal.

Because water is held by capillary forces within unsaturated soil pore spaces, its water potential is negative, indicating that the water is under tension and that work must be done to extract water from the soil. A water potential reading of zero indicates that the soil is saturated, and plant roots may suffer from lack of oxygen. As the soil dries, water becomes less available and the water potential becomes more negative. The negative sign is usually omitted for convenience when soil water potentials are measured with tensiometers, and readings are reported as soil water tensions.

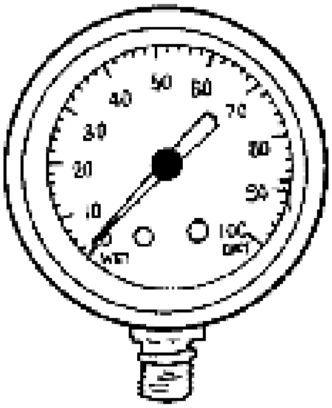

Fig. 2- Pressure gauge

1.2.3 RANGE OF OPERATION

Because of the vaporization of water at low pressure, the range of operation of a tensiometer is limited to 0 to about 85 cb. Above 85 cb the column of water in the Plexiglas tube will form water vapour bubbles (cavitate), and the instrument will cease to function. This range represents only a fraction of the water tension range that is normally considered to be available for plant growth. Many plants can survive to a water tension of 15 bars. However, plant growth and productivity cease well before this point. In sandy soils, tensiometers measure the entire range of soil water tension of interest for irrigation.

Research has shown that to optimize production, irrigation should be scheduled when soil water tension reaches 10-20 cb in sandy soils. The exact values to be used depend on soil hydraulic properties, crop susceptibility, and production objectives. These water tensions are well within the tensiometer range of application.

1.2.4 SITE SELECTION

Tensiometers measure soil water tension in only a small volume of soil immediately surrounding the ceramic cup. Therefore, the ceramic cup must be placed in the active root zone of the crop for which irrigations are being scheduled. Depending upon crop type, two or more tensiometers may be required at a measurement site. Figures given below illustrate proper depths of installation for row crops and tree crops, respectively.

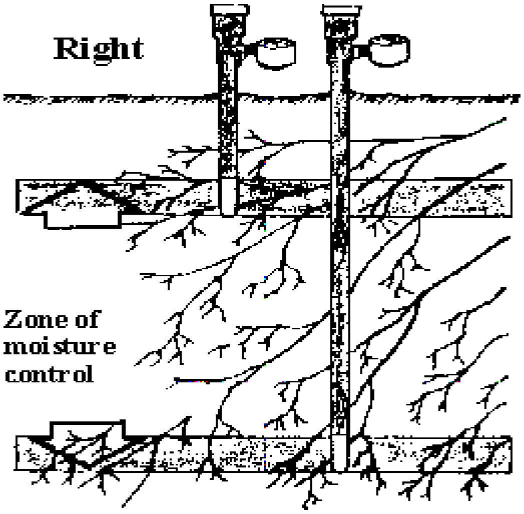

Fig.3 - Alignment of tensiometer in root zone

Because of differences in soil and plant characteristics, several measurement sites may be required to adequately assess the water status of large areas. For more valuable or more sensitive crops, more tensiometers should be used. For uniform soil types fewer tensiometers may be adequate.

The sites selected for installation should be representative of the surrounding field conditions. Isolated low, wet areas or high, dry areas should be avoided. Tensiometers should be placed within the plant canopy in positions where they will receive typical amounts of rainfall and irrigation. Placement of tensiometers with depth is critical. For shallow-rooted (less than 30 cm) crops such as some vegetables, only one tensiometer may be required with depth. It should be centred in the crop root zone, but at least 10-15 cm below the surface. The ceramic cup should not be exposed to the atmosphere.

For crops with deeper root zones such as most field crops, two tensiometers should be used at each measurement site. The shallower one should be placed in the zone of maximum root concentration. This is normally at 15 cm or about one-third of the active rooting depth. In tree crops, depths of 15 to 60 cm are often used. Other depth combinations may be used where appropriate. When multiple instruments are used, most irrigation will be scheduled to replenish the upper part of the root zone monitored with the shallow instrument. The deeper instrument will indicate when less frequent larger irrigations are needed to replenish the root zone.

1.2.5 INSTALLATION

The tensiometer can be a useful instrument for irrigation scheduling only if it is properly installed. In general, proper installation requires that the instruments be in good hydraulic contact with the surrounding soil so that water can move into and away from them as efficiently as possible. In addition, tensiometers must be properly located in the crop root zone as discussed in the previous section on site selection.

Before field installation, each tensiometer should be tested to verify that it is operating properly. Fill each tensiometer with clean water (deionised water is preferred to help prevent organic growths) and allow it to stand in a vertical position for at least 30 minutes so that the ceramic tip will saturate. A plastic squeeze bottle and small diameter plastic tube can be used to fill the tube from the bottom to help eliminate air bubbles.

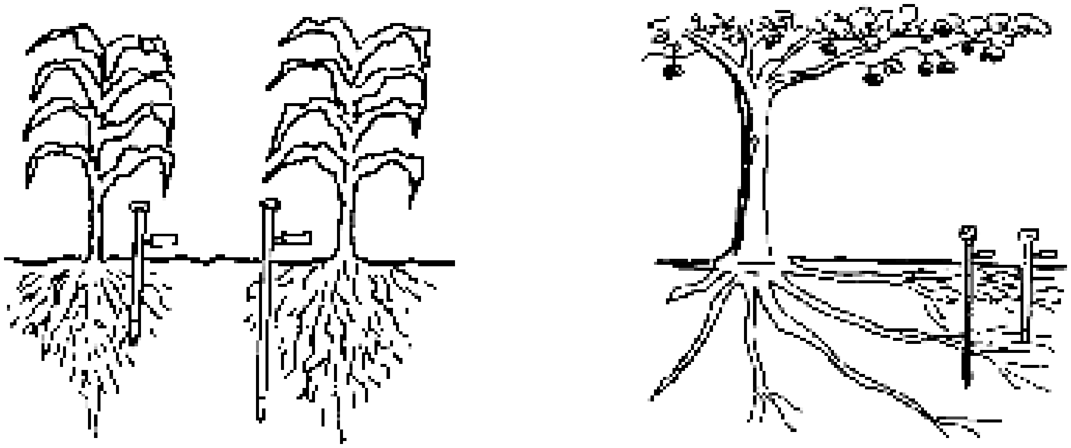

Fig. 4- Installation of tensiometer in the field

When its tip is thoroughly wetted, it can be refilled and capped. The tensiometer will not be serviceable immediately because of air bubbles in the vacuum gauge. A small hand vacuum pump, obtainable from tensiometer manufacturers, can be used to remove air bubbles and test for air leaks. This service will be necessary before installation as well as periodically in the field.

Tensiometers are installed in previously cored holes in the field. Coring tools of the proper dimensions are available for tensiometer installation. In sandy soils, the access holes can be cored by hand, while on heavier soils it may be necessary to use a hammer to aid the installation.

The tensiometer is pushed into the access hole to the proper depth. In this position, the vacuum gauge will be located 5-8 cm above the soil surface. The soil around the tensiometer should be tamped at the surface to seal the instrument from air contact with the ceramic cup and to prevent surface water from running down around the tube.

If commercially available coring tools are not available, a length of standard water pipe or other tubing of the proper diameter can be used with acceptable results. It is critical, regardless of the installation method used that the ceramic cup be in intimate contact with soil in order for the tensiometer to function properly.

If a rock or other obstacle is encountered, the tensiometer should be moved to another location to avoid possible damage when it is placed in the cored hole. The tensiometer should not be driven into the place with a hammer or other object. Although adequate for normal use, the mechanical strength of the ceramic cup is not adequate to allow it to be hammered into place.

In very loose cultivated soils, such as frequently encountered in commercial row crop production, it is possible to push shallow tensiometers into place without coring a hole. This method of installation is acceptable when applicable. Again, the surface soil must be firmly packed around the instrument after installation.

After installation, several hours may be required before the tensiometer reads the correct soil water potential value. This is because of the disturbance to the soil caused by the installation procedure, and because of the need for water to move through the ceramic cup before equilibrium is reached. The correct reading will be reached more quickly in moist soils than in dry soils. After this initial equilibrium period, the tensiometer will accurately indicate the soil water tension, and it will closely follow changes in tension as they occur in the soil. Tensiometers are delicate instruments and should be protected from harm both before and after installation. They should be handled carefully and protected from impact by the equipment or animals in the field. Also freezing conditions will damage tensiometers. They should not be left filled with water during freezing conditions.

1.2.6 FIELD SERVICE

To operate properly, tensiometers must be serviced in the field periodically. This is because with normal use, air is extracted from water under tension. The air becomes trapped within the tensiometer and reduces response time progressively until the instrument fails to operate. If the soil in which the tensiometer has been installed is moist, soil tensions will be low and very little air will accumulate. If, however, the tensiometer is installed in drier soils, with water potentials in the range of 40 to 60 cb, air will accumulate more quickly. The body tube should be inspected for accumulated air each time the tensiometer is read. If over 1/2 cm of air has accumulated beneath the service cap, the cap should be removed and the tube must be refilled with water. In wet soils, the tensiometer will probably need to be serviced approximately every two weeks. In dry soils, servicing may need to be more frequent, perhaps as often as every time the tensiometer data is collected.

1.2.7 IRRIGATION SCHEDULING

Tensiometer measurements are useful in deciding when to irrigate because they give a continuous indication of soil water status, but they do not indicate how much water should be applied. The decision to irrigate is made when the average tensiometer reading exceeds a given critical value. To optimize production, the critical value is normally in the range of 10 to 20 cb for typical sandy soils. The critical values are different for specific soil types, crops, and stage of crop growth. At critical stages of crop growth, lower values are used, resulting in irrigations being scheduled more frequently. The critical values are also functions of economic considerations, with higher values set if the irrigated commodity price drops or if the cost of irrigation increases.

A tensiometer indicates only when the irrigation should be scheduled, and not how much water should be applied. To determine the amount of water to be applied, a moisture characteristic curve specific for the irrigated soil must be used. The figure shows a moisture characteristic curve for Lake Fine Sand, a typical deep sandy soil. The depth of irrigation water to be applied should be adequate to restore only the root zone to field capacity. Excessive water will be lost to deep percolation below the crop root zone, carrying nutrients with it.

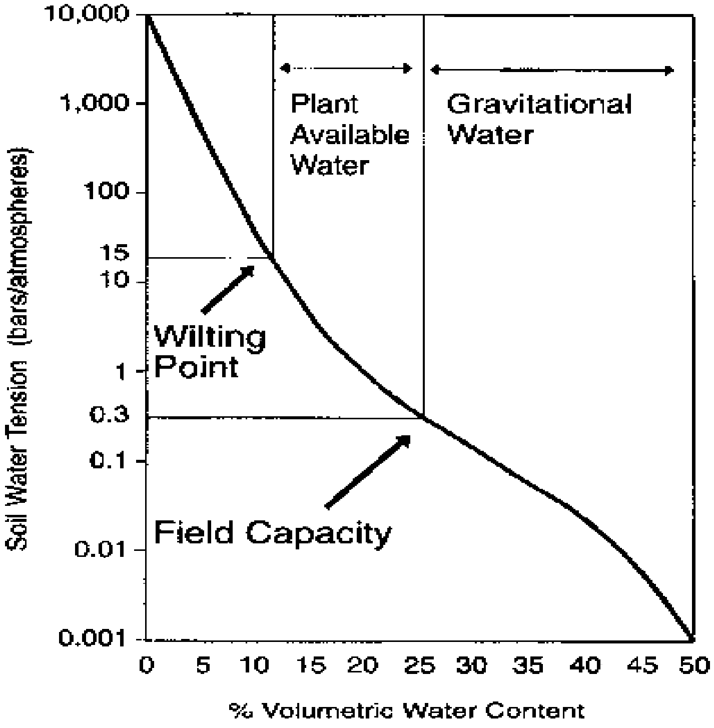

Fig 5. Soil moisture characteristic curve

1.3 TYPES OF IRRIGATION CONTROL SYSTEM

1.3.1 Automated Irrigation Control System

A major advantage of tensiometers is that they can be instrumented to provide automatic control of irrigation systems. A modification is required to allow a tensiometer to be used as an irrigation controller. The vacuum gauge is equipped with a magnet and a magnetic pick-up switch so that, when a desired (and preset) water tension occurs, the switch closes, starting the irrigation pump. The pump operates for a preset period of time, lowering the tensiometer reading, after which the tensiometer is again monitored until the critical water tension again occurs.

1.3.2 Pneumatic Irrigation Control System

In this, a diaphragm acts as a pressure sensor which activated either an electrical switch or a pilot valve for switching the flow of irrigation water ON and OFF. The rate of irrigation flow was not variably controlled by the pilot valve. A commercially available control system uses magnetic proximity switches which are positioned on the face of the vacuum-gauge indicator needle and either activate or deactivate an electrical irrigation control valve.

1.3.3 Solenoid Irrigation Control System

This system consists of a solenoid operated hydraulic control valve which was actuated to open at times when irrigation was needed and closed when enough water was applied to soil.

1.4 AIM

To develop a tensioemitter - an emitter automatically controlled by soil moisture tension.

1.5 OBJECTIVES

To develop and fabricate a tensio-emitter with the following characteristics:

a) operate without external power requirement.

b) Simple in design.

c) Low cost of construction.

d) High reliability.

e) Simple adjustments.

Review of Literature

REVIEW OF LITERATURE

Rawlings and Dalton (1967) introduced the use of thermocouple psychrometers in situ appears to be feasible to measure the total potential of water.

Peck and Rabbidge (1969) conducted a study to measure the performance of an Osmotic Tensiometer for measuring capillary potential in which an osmotic tensiometer makes use of a confined aqueous solution, instead of pure free water, as the reference state in measuring soil-water potentials. The membrane separating the confined solution from the soil water is highly impermeable to the confined solute but exchange of much smaller molecules and ions occur. Thus the capillary potential of soil-water is measured unless soil solutes are excluded by the instrument by a vapour gap. The advantage of this instrument over conventional tensiometers is that measurements of capillary potentials are made through out the range 0-15 bars. Tests and observations show that osmotic tensiometers can be useful for measurements of capillary potential at depths greater than about 10 cm during the redistribution of soil water and its uptake by the plants.

Peck and Rabbidge developed a modified tensiometer, which uses as the reference potential an osmotic solution instead of pure water at atmospheric pressure.

Bakker (1978) reported that some air leakage occurred through tubing connections and a small water reservoir is required to flush excess air out of the tubing during connection of the transducer to each tensiometer.

Marthaler *et. al.* (1983) conducted a study for introducing a pressure transducer system for field installed tensiometers. The system consisted of a pressure transducer with attached syringe needle and digital read-out. The needle was inserted through the septum stopper which closes the upper end of the tensiometer. The pressure in the air below the septum stopper, in equilibrium with the water pressure is read on the digital read-out, which is calibrated in milli bars.

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Cassel and Klute (1986) reported that unless the transducer - tensiometer system is operated under constant temperature conditions, temperature fluctuations can affect the output of the system.

Dowd and Williams (1989) showed that recent developments in electronic data acquisition and inexpensive thermally stable pressure transducers provide additional possibilities for rapid response recording of multiple tensiometers.

John and Barry (1990) used tensiometer data acquisition system for hydrologic studies requiring high temporal resolution. Commercially available differential pressure transducers, tensiometers and a data acquisition system were combined to evaluate soil water tension changes with time within two landfill cover designs used for shallow land burial of waste materials. A typical error for the differential pressure transducers in the voltage-pressure calibration curve was estimated to be 0.14 V at a transducer output of 4V. The utility of tensiometer data acquisitions system to collect field data was demonstrated successfully using reference tensiometers with known hydraulic heads. Diurnal fluctuations in tensiometer data collected in the field are discussed relatively. Also tensiometers with unknown or variable heads were used to determine tensiometer response time of approximately 50 min.

McDonnell (1993) made a comparison between electronically multiplexed system and fluid multiplexed system. Results showed that for detailed hill-slope rainfall-runoff research, electronically multiplexed systems are superior to fluid multiplexed systems because individual tensiometers can be scanned, and data stored more easily, at much shorter time increments.

Peterson *et. al.* (1993) developed a simple irrigation control valve that mechanically links the soil water potential to the position of a piston that controls the flow of water through the valve. In this, no external power was required. Here, irrigation level was controllable and flow increased as tensiometer pressure decreased due to soil dryness. Initial pressure setting for valve opening was easily adjustable to accommodate different irrigation requirements. This valve was useful in controlling soil water content in a small area or in a large area of uniform soil properties and water requirement, and permit better utilization of water.

Smajstrla *et.al.* (1996) used tensiometers to automatically schedule irrigations whenever the soil matric potential reached that which was required for the tomatoes. In this, tomatoes were grown on a fine sandy soil using drip irrigation and polyethylene mulch to evaluate the effects of irrigation scheduling on irrigation requirements and yields under typical conditions. Here, automated irrigation was clearly demonstrated to be a necessary function as total marketable yields were almost doubled by automated irrigation, while yields of high-value extra-large fruit were almost tripled by automated irrigation as compared to the irrigation control. This demonstrates that water stress caused by even the relatively small differences in soil matric tensions studied produced statistically significant reductions in the yield of the highest-value, extra-large fruit, which would have the greatest impact on producers.

2.1 DETERMINATION OF SOIL HYDRAULIC PROPERTIES

Corey and Kemper (1961) presented analytical and experimental evidence that no single function in terms of state of the fluid alone can be indicative of the magnitude or even the direction of net transport of water for all cases.

Dane and Hruska (1983) applied parameter estimation methods to the determination of in situ hydraulic properties using input data consisting of water content profiles at different times during gravity drainage of a clay with a zero flux condition at the soil surface.

Corey, A.T. and Klute, A. (1985) conducted a study which examines the view that "total soil water potential" can be defined such that the water component will always move from regions of higher to regions of lower potential and that if the total water potential is constant at all points the water component is in equilibrium. Concepts from texts dealing with transport processes and thermodynamics are used to show that there is no single potential that is a function of state of soil suction only, whose gradient will always indicate the direction of net transport of the water component or which if constant in all parts of the system will ensure that equilibrium exists.

Parker, J. C., Kool, J. B. and M. Th. Van Genuchten (1985) determined soil hydraulic properties from one-step outflow experiments by parameter estimation. Unsaturated hydraulic properties of four soils of varying particle size distributions were evaluated by determining values in five parameters in van Genuchtens hydraulic model. Saturated conductivities and saturated water contents were directly measured and the values of residual water content and parameters were evaluated by a non linear inversion method to minimize various objective functions.

Baker and Allamars (1990) described an automated multiplexing system that can provide a continuous measurement of soil water content in many locations in the field. Field determination of water flow or the changes in the soil water content under two or three-dimensional flow regimes has been different because of its highly dynamic nature.

Jensen et al.(1990) stated that research is needed to achieve improved on farm systems that would facilitate the application of lighter and more timely irrigations in order to minimize crop water stress and excess water applications.

Eching, S.O. and Hopmans, J.W. (1993) conducted a study the objective of which was to experimentally explore the feasibility of using both cumulative out flow and soil water pressure head data in the inverse solution for laboratory determination of soil hydraulic functions using both one step and multistep outflow experiments Soil water pressure head was measured with a micro Tensiometer and pressure transducer. Desorption experiments were performed under both pressure and suction for different types of soils.

Ole Wendroth, W. Ethlers, J.W. Hopmans, H. Kage, J.Halbertsma, and J. H. M. Wosten (1993) conducted a simple evaporation method for the determination of hydraulic conductivity function and the water retention characteristics was developed and applied to a range of soils with different texture and structure. During evaporation from the top of 6cm high soil core, soil water pressure head at 1.5 and 4.5 cm below the soil surface was measured with tensiometers several times. At the same time evaporative water loss was determined by weighing the water column. The procedure for calculating hydraulic functions as evaluated via numerical simulations. A limitation of this method is that, at water contents near saturation where hydraulic conductivity is high, hydraulic gradients cannot be determined accurately.

Tetsu Tokunaga and Rohit Salve (1994) found potential applications of air pocket type tensiometers in measuring hydraulic head profiles in deep vadose zones and found that these method has advantages such that the ability to obtain tensiometer measurements far beyond approximately 9m depth often associated with the limit of conventional tensiometry, ease of regular gauge calibration, and low cost. Advantages relative to buried, dedicated pressure transducer tensiometers are gained at the expense of substantial losses.

Timlin, D. J., Ahuja, L. R. and Ankey, M. D. (1994) conducted a study the objective of which was to investigate some field oriented methods designed to characterize the flow rates of both the soil matrix and macro pores near saturation. Apparent macro pore conductivity was obtained by the difference between saturated and unsaturated hydraulic conductivities at -0.6 kPa of soil water pressure. Saturated conductivities were measured in double ring infiltrometers with tensiometers .Soil matrix conductivities were calculated from measurements of soil water pressures and drainage rate during redistribution and were also measures with thin sand –cement crust. Another set of data for saturated and unsaturated conductivities was obtained from unconfined ponded measurements in 76.2mm-diameter rings and a tension infiltrometer.

Santini et al. (1995) also used parameter estimation in connection with evaporation experiments and compared the results with independently collected retention data. In spite of the promising results; Halbertsma stated that evaporation experiments are not suitable for inverse modelling because of uniqueness problem.

Darusman, Akhter H. Khan, Loyd R .Stone and Freddie R. Lamm (1997) conducted a study the objective of which was to evaluate the water flux below the root zone with a subsurface drip irrigation system. Use of micro irrigation is increasingly, prompted by factors such as a greater ability to control losses of water and nutrients from the root zone. Tensiometers were placed below the drip line and at increments of 0.4m from the drip line at soil depths of 1.4 and1.7m.The crop were corn planted in rows spaced 0.76m apart. Water flux was calculated by using a hydraulic conductivity vs. matric potential relation ship and Darcy’s equation It was found that if spacing between drip lines is increased beyond 1.5m in silt loam soils there would be an associated increase in internal drainage from root zone and decrease in corn yields.

Dong Wang, S.R. Yates and F. F. Ernst (1998) conducted studies to measure soil hydraulic properties using tension infiltrometers. Tension infiltrometers has become a popular instrument for field determination of soil hydraulic properties. To develop and test different models for parameter estimation based on tension infiltrometer measurement, simultaneous measurements of transient tension infiltration rate, soil water content, and tension using small time domain reflectometry probes and tensiometers installed at fixed locations relative to infiltrometer disk. Infiltration was made with 10 and 20cm diameter disks under 1 and 5cm of water supply tensions. The sorptivity method produced *K*, estimates that were statistically similar to those obtained from Wooding's method.

Jiri Simunek, Ole Wendroth, and Martinus Th. Van Genuchten (1998) conducted studies for parameter estimation analysis of evaporation method for determining soil hydraulic properties. Soil hydraulic properties are important parameter affecting water flow in variably saturates soils. In this method first step is to estimate the hydraulic properties from a laboratory evaporation experiment using both parameter estimation method and the modified wind method. The parameter estimation method combined a one-dimensional numerical solution of the Richards equation with the Marquardt-Levenberg optimization scheme. In this study we use both numerically generated data and data measured in the laboratory. Two experiments were carried out on 10 cm high soil cores containing two different soils. Pressure heads inside the cores were measured with five tensiometers, while evaporative water loss from the top was determined by weighing the soil samples. The objective function for the parameter estimation analysis was defined in terms of final total water volume in the core and pressure readings by one or more tensiometers.

Warrick, A.W. (1998) conducted an experiment to estimate soil water diffusivity from experimental absorption data. The purpose was to directly match measured sorption curves to scaled forms of the solutions and thus provide consistent hydraulic properties. Evaluation of such parameters is critical to prediction of water and solute transport within the vadose zone. Generally the results gave two independent relation ships of the parameters. An example was considered and calculations performed for three alternate models. The best choice of each model was easily found and the evaluated parameters were shown to be consistent. The soil water diffusivities were compared for the estimated parameters.

Materials and methods

MATERIALS AND METHODS

3.1 LOCATION

The experiment was conducted in K. C. A. E. T. campus at Tavanur in Malappuram district. It is situated at 10º 52’ 30” North latitude and 76 º East longitudes. The total geographical area of the campus is about 40.25 ha.

3.2 MODEL OF WORK

The proposed tensio-emitter was envisaged to be consisting of a sensor – which is a porous cup taken from a tensiometer, and a watering head which permits filling of the sensor with water and opens or closes the micro tube applying water to the plant.

Initially, the porous cup was coupled to a plastic pipe with a piston supported by a metal frame. A small diameter flexible pipe was allowed to pass between the piston top with one end of pipe connected to the main irrigation line. Due to the suction in the soil, there is a downward movement of the piston. As a result, the water flows freely through the flexible pipe to the plant root zone. When the field capacity is reached the piston moves upwards and the flow is cut off.

3.3 DESIGN PARAMETERS

In designing a tensiometer, two critical properties can be controlled, the porous ceramic conductance (C) and the gauge sensitivity (S), which is the volume displacement necessary for the gauge to register a certain pressure change.

Any tensiometer has a non-zero response time, because of the volume of water that must be moved across the porous cup of the instrument to register a pressure change in the water in the tensiometer. The gauge sensitivity and cup conductance of the tensiometer and the conductivity of the soil in which the tensiometer is placed will determine the overall response of the instrument to changes in soil-moisture tension. The water that is transferred across the tensiometer cup constitutes the disturbance of the soil-water system. The instrument response time, T_R, has been defined by Richards to be $1/KS$, where K is cup conductance, and S the gauge sensitivity. The gauge sensitivity is the pressure change per unit volume of fluid transferred to or from the tensiometer.

The flux of water across the cup is given by:

$$dq/dt = K\,(\psi_S - \psi_T) \qquad (1)$$

where ψS is the suction just outside the cup in the soil-water system and ψT is the suction in the water in the tensiometer ceramic cup. Both of these may vary with time. Equation (1) may be written as:

$$(1/K)*(dq\,/\,d\psi_T)*(d\psi_T/\,dt) = \psi_S - \psi_T$$

Making use of the fact that $dq/d\psi T$ is the reciprocal of the gauge sensitivity S we may then write:

$$T_R\,*(d\psi_T/\,dt) = \psi_S - \psi_T$$

The cup conductance is defined as

$$C^* = C/2\pi rK$$

Where

C^* = conductance of the ceramic cup (ml/s/cm water at 20ºC)

K = hydraulic conductivity (cm/sec)

r = cup radius (cm)

and gauge sensitivity is expressed as

$$S^* = SCr^2/D$$

As the cup conductivity (C^*) increases, the system eventually becomes soil-limiting; as gauge sensitivity (S^*) increases, the system also becomes soil-limited.

3.4 DEVELOPMENT OF THE PROTOTYPE

The tensiometer porous cup was coupled with a plastic pipe having a piston (plate 1). A micro tube was allowed to pass in between the piston and the frame. Sufficient suction was achieved but the piston was not moving down. To reduce the friction, the contact area of the piston was reduced. This was not successful. Hence weight is added to the top of the piston. However, the reverse flow when the soil is saturated was not occurring as the pressure developed was not sufficient to overcome this weight.

Plate 1. Arrangement of tension-emitter with a single porous cup and piston

Then a filter candle joined with a cylinder and piston was tried (plate 2). Due to the high porosity of the filter candle sufficient pressure was not developing. Hence it was also a failure.

Plate 2. Model of tensio-emitter using filter candle as sensor

In order to develop sufficient negative pressure two porous cups were connected together by a T-joint and bends (plate 3). A transparent pipe of 5 mm diameter used to monitor the water level rise and fall. Complete expulsion of air was not possible and monitoring as well as filling turned to be a problem.

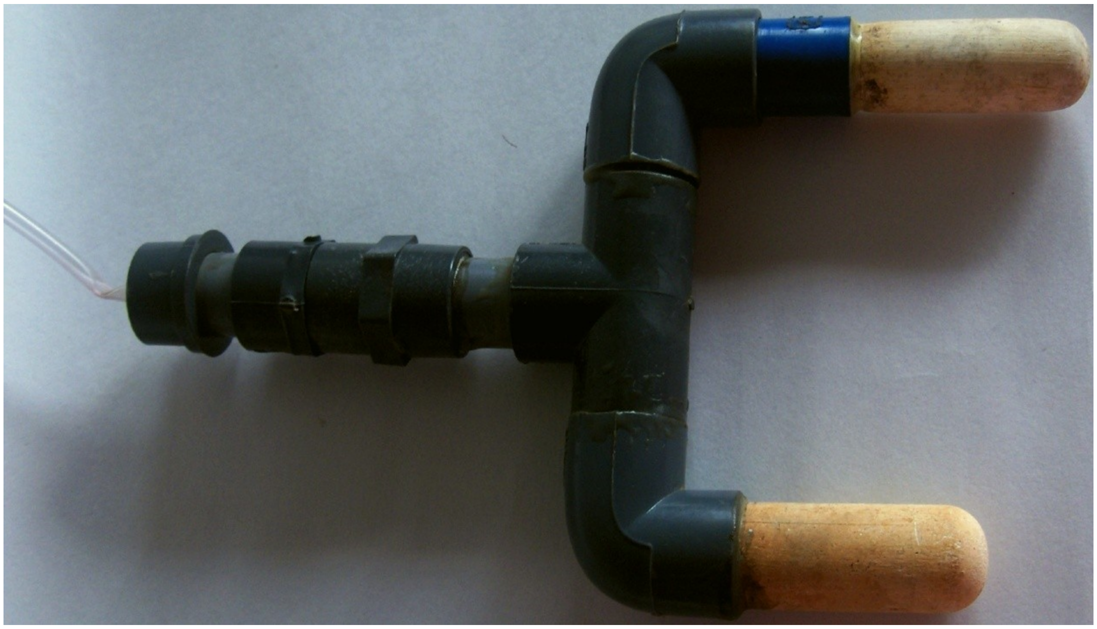

Plate 3. Model of tensio-emitter with two porous cups as sensing unit

Hence many porous cups were tested using a tensiometer. The design was modified by using a frame, two end plugs, diaphragm and a screw mechanism. A moveable rectangular frame of mild steel was fitted on a coupling with two nuts and bolts at opposite sides. On the top of the frame, a wooden end plug with bolt and nut with a guide to restrict the movement was provided. The whole mechanism was connected to the pipe.

Plate 4. An overall view of valve assembly

The working of the valve was automatically controlled by the diaphragm (plate 5) in response to the soil moisture tension. A diaphragm made from a thick balloon was fixed over the coupling. The diaphragm moved up and down with change in the moisture content of the soil, moving the peg along with that thus opening and closing the micro tube by squeezing and releasing it (plate 6).

Plate 5. A view of working of diaphragm

Plate 6- The zero adjustment of the tensio-emitter

Results and Discussions

RESULTS AND DISCUSSIONS

The results of the work done to develop an automated irrigation control valve, The Tensio-emitter, are presented in this chapter. The section also details about the calibration of the system. Based on the soil water potential measurements a tensio-emitter was developed and evaluated as per the methodology. The system was evaluated for the successful operation for a week continuously.

4.1 SET-UP OF THE TENSIO-EMITTER SYSTEM

The sensor which is the porous cup of a tensiometer is one of the important parts of the tensio-emitter system and hence its filling is of paramount importance. Before filling the sensor it is advisable to keep it in water for sometime, preferably for an hour. This allows the ceramic material enough time to absorb water fully and reduce the pressure built up during the process of sealing. For the purpose of filling the sensor, unscrew the watering head and fill it to its brim with water. After filling, screw the watering head back on to the sensor firmly so that it is airtight but not too tightly to cause striping of the screw. The sensor works best only if it has been filled without air entering the system. It is therefore advisable to fill it while holding under water.

The sensors should not be inserted into dry or semi-dry soil. So before inserting into the soil, the soil should be watered thoroughly for several times. Optimally, the watering should be done about every 10 minutes, 2-3 times so that the soil is somewhat too wet. The sensor should be placed in the earth, near the roots. The upper edge of the porous cup should be about 1 cm under the surface of the soil and it should have good contact with the surrounding soil. The system should first be completely set-up before any adjusting on sensors is done.

4.2 ADJUSTMENT OF THE TENSIO-EMITTER

Before using the system it has to be checked for water tightness as well as air tightness. Then turn on water to the drip hose. For the purpose of running test, turn the adjusting screw on the watering head till a strong stream of water flows out of the drip tube. Drip distance is another important factor. The distance from the drip location to the sensor (porous cup) influences the length and amount of watering. The drip tube must stick out about 8 cm beyond the watering head.

4.2.1 Standard Adjustments

Slowly close the adjusting screw until just a single drop of water remains hanging on the end of the drip tube. This "zero adjustment" ensures that the sensor shuts off automatically when enough moisture is available (i.e. after rain or irrigation). If the zero adjustment is done before the sensor adapts to the soil moisture (i.e. equilibrates), two more additional turns are required. If the adjustment of the sensors takes place 3-4 hours, after insertion in the wet earth, the sensor will have more time to adapt to the soil's moisture and then the additional closing of two turns is usually unnecessary.

4.2.2 Calibrations and Correction

Adjust the sensor on the following days for about a week. Dripping should start when the earth surface is dry; otherwise, open the adjusting screw a little. If the earth remains wet, then drips should not be seen even gradually emerging from tube; in this case, close adjusting screw more. Usually an adjustment of half a turn is enough. Proper adjustment requires a certain degree of delicate touch.

When a more intensive watering is desired for specific plants, increase the distance between the drip end and sensor to 10-15 cm, thereby increasing the duration of watering (the water has a longer way to reach the sensor). If the distance is more than 8 cm, for potted plants the extra water may drip out of the pot.

For moisture sensitive plants, decrease the distance between drip end and sensor to about 4 -5 cm so that watering is more quickly accomplished and less water reaches the pot. Adjusting for drier conditions should not be done over the screw setting, because this would lead to the water in the tensio-emitter to be quickly used up.

Summary and Conclusion

SUMMARY AND CONCLUSION

An experimental study to develop a tension-emitter i.e. a tension controlled emitter was conducted at K.C.A.E.T, Tavanur during the period 2006-2007. It is an automated emitter that worked based on the tension caused due to the fluctuations in soil water content to initiate and stop irrigation.

The developed tension-emitter consists of a porous cup and a watering head assembly. The porous cup has the same function as that in a tensiometer where it acts as a sensor which equilibrates the tension inside the tensiometer to that of the surrounding soil. The watering head consists of a diaphragm, an adjustable screw and two triangular heads. The micro tube supplying water to the plant passes between the triangular heads. One of the triangular heads is attached to the diaphragm which moves according to change in the soil moisture and the other to the adjustable screw head so that it can be moved up and down by turning the screw. The tension-emitter is calibrated by adjusting the screw so that water flows through the micro tube only when the soil becomes dry and closes the micro tube when the soil receives enough water.

The results obtained from the experimental studies indicated that it is most important to calibrate the tension-emitter for its proper working. First the soil is completely saturated by applying water two or three times and the screw is turned till no water drips from the micro tube. The micro tube will open and water drips when the soil becomes dry. It was found that fine adjustment of the screw every day for about one week was sufficient for the proper functioning of the tension-emitter. The distance of the drip point of the micro tube from the sensor is found to be quite important as that is the factor which controls the amount of water applied to the soil before the closing of the micro tube. When the tension-emitter is used for potted plants a distance of 8 cm was found to be satisfactory. However, this distance depends on the soil type and the plants – water sensitive plants requiring less distance and plants needing more water requiring more distance.

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The Tensio-emitter was successfully developed, fabricated and calibrated for use in potted plants. Significantly less water was applied depending upon the soil moisture tension. This prototype can be modified by incorporating the whole assembly to a single plastic emitter.

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Abstract

DEVELOPMENT OF A TENSIO-EMITTER

- A TENSION CONTROLLED EMITTER

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ABSTRACT OF THE PROJECT REPORT

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ABSTRACT

Timely application of irrigation water in precise amounts increases crop yield due to decreased moisture stress to plants and decreases loss of water through percolation and subsequent nutrient leaching. Many times, automatic scheduling of irrigation is desired as it ensures timely and precise application and reduces labor cost. Automatic scheduling of irrigation usually involves sophisticated instrumentation which is expensive and requires external power. Irrigation can be scheduled by measuring the moisture tension in the soil which indicates the amount of water available to the crop. A system which utilizes the sensed moisture tension to directly control the water applied without using an external power source is desired. The tesiometer controlled irrigation control valve developed earlier could achieve this but the fabrication of the valve assembly was quite sophisticated. In this study an attempt is made to develop and fabricate a soil moisture tension controlled irrigation emitter which is simple to fabricate and doesn’t involve the use of any external power sources.

The developed tension-emitter consists of a porous cup and a watering head assembly. The porous cup has the same function as that in a tensiometer where it acts as a sensor which equilibrates the tension inside the tensiometer to that of the surrounding soil. The watering head consists of a diaphragm, an adjustable screw and two triangular heads. The micro tube supplying water to the plant passes between the triangular heads. One of the triangular heads is attached to the diaphragm which moves according to change in the soil moisture and the other to the adjustable screw head so that it can be moved up and down by turning the screw. The tensio-emitter is calibrated by adjusting the screw so that water flows through the micro tube only when the soil becomes dry and closes the micro tube when the soil receives enough water. Tensio-emitter was successfully developed, fabricated and calibrated for use in potted plants.