and with herbicides provided significantly better control of RIFA through 6 weeks and remained superior at 8 weeks after treatment as compared to control. In treated plots there was an increase in RIFA population in 10 weeks time, and the number of infested cards increased to the level of untreated control.

There was a slight problem in mixing chlorpyrifos with bromacil + diuron 11 80 DF, simazine-s, ametryn, and oryzalin, but the efficacy of herbicides was not affected except in the case of ametryn. Therefore, chlorpyrifos can be applied in a tank-mix with herbicides except ametryn. In cases where slight physical incompatibilities exist, continuous and vigorous agitation should be maintained in the tank. This will facilitate a homogeneous suspension and allow the uniform application of all components present in the tank-mix. These results indicate that chlorpyrifos and ametryn should not be applied together as a tank-mix. Herbicides did not affect the suppression of RIFA by chlorpyrifos, and therefore, these herbicides can be tank-mixed with chlorpyrifos for RIFA suppression in citrus groves.

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USE OF TENSIOMETERS FOR SCHEDULING OF CITRUS TRICKLE IRRIGATION

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Abstract. **Tensiometers were used to automatically schedule trickle irrigation of citrus in a field research project. Commercially available magnetic switching tensiometers were installed with irrigation timer-controllers. Tensiometers initiated irrigation events when soil water potential dropped to preset levels. Controllers applied a predetermined amount of water at each irrigation. The system responded to the soil water status when tensiometers were located in the irrigated citrus root zone, and when they were regularly inspected and periodically calibrated. Maintenance requirements and causes of failures of the system during three years of field experience are discussed.**

In Florida there is increasing competition for the use of fresh water supplies among municipalities, industry and agriculture. Because agriculture is the largest user (2), it is important for agricultural producers to use irrigation water as efficiently as possible. Efficient use means providing for a crop's water requirements to obtain the optimum level of production with as little waste as economically feasible. Efficient water use minimizes pumping and related costs of water application, and therefore, potentially increases profits from production systems.

One means of increasing the efficiency of water use for irrigation is by scheduling irrigations. Optimal scheduling is achieved by irrigating only as frequently as required to prevent yield-reducing water stress so that the greatest economic return will result from the production system.

Accounting methods for irrigation scheduling of citrus in Florida have been reported. Koo (6) used an evapotranspiration curve developed in earlier research (3). Accounting procedures based on long-term average crop water use (1, 12), or long-term average pan evaporation as an index of crop water use have also been utilized (8, 11).

In some studies (5, 7), the neutron probe has been used to directly measure soil water depletions from citrus root zones. This approach allowed irrigations to be scheduled only when required, because the direct measurement of soil water status accounted for day-to-day variations in

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climatic conditions rather than relying on estimated soil water storage characteristics and long-term average climatic conditions.

Tensiometers directly measure soil water potential (SWP), which is a measure of soil water status and water availability to a crop (9). Tensiometers have previously been used successfully to schedule irrigation of lemons in Florida (4). In that study, tensiometers were periodically read and irrigations were scheduled manually as a result of the readings.

Tensiometers have the advantages of being able to continuously monitor SWP, and to close magnetic switches when a critical SWP is reached (10). Because of these features, tensiometers were installed to automatically schedule irrigations in a citrus trickle irrigation field research project we initiated in March, 1984. The specific objectives of this research project were to determine the effects of SWP, fertigation, and wetted volume of the root zone on citrus irrigation requirements and yields. This paper will report results of our experiences with the use of tensiometers to automatically control irrigation systems under field conditions.

Materials and Methods

This research was conducted at the IFAS Citrus Research and Education Center, Lake Alfred. Mature 'Valencia' orange [*Citrus sinensis* (L.) Osbeck] trees on rough lemon rootstock (*C. jambhiri* Lush) were irrigated with drip and spray types of trickle irrigation systems. The soil type was Astatula fine sand.

One spray emitter and six drip emitters were used per tree. The spray emitters applied 16 gallons per hour (gph) over a 17 ft diameter of coverage at a pressure of 20 psi. The drip emitters applied 2 gph with about a 3 ft wetted diameter at the same pressure.

Irrometer vacuum gauge tensiometers (Irrometer Co., Riverside, CA) equipped with magnetic pickup switches on the vacuum gauges were used to automatically schedule irrigations. The magnetic switches are normally closed. They are held open by a magnet on the vacuum gauge needle. When SWP decreases (increasing vacuum), the vacuum gauge needle and magnet rotate, closing the magnetic switch. SWP at switch closure is set by positioning the magnetic switch over the desired vacuum gauge reading.

The magnetic switching tensiometers were used with Irrometer irrigation controllers to schedule irrigations. The controllers provided 24 VAC signals to relays at preset possible irrigation times per day. The relays, in turn, provided power to open electric solenoid valves. The 24 VAC signal is interrupted by the tensineter magnetic switches until switch closure occurs at the preset SWP. The switch closure completes the electrical control circuit, and at the next permissible irrigation time, a solenoid valve opens.

Mechanical clocks were used to control irrigation events. Maximum possible irrigation times per day are set by positioning pins on a clock wheel. A microswitch is closed when it contacts the pins as the clock rotates. The controller uses a "lock-in" relay which causes irrigation to continue for the preset time period once initiated by a tensiometer switch.

Six irrigation treatments were instrumented. Two banks of three tensiometers each were installed in each treatment, for a total of 36. Tensiometers in each bank were installed at three depths, 6, 12, and 36 inches, and they were wired in parallel. This permitted any individual tensiometer to initiate an irrigation event.

Tensiometers were installed under the tree canopies and near the drip line. They were located well within the irrigated soil zones so that they would respond to irrigation applications. They were located about 6 ft from the spray emitters and about 6 inches from the drip emitters.

Tensiometers were carefully installed using a coring tool made specifically for this purpose. The coring tool allowed the proper diameter hole to be dug so that tensiometers were installed in good hydraulic contact with the soil. Soil was well compacted around the tensiometer to prevent water from flowing to the ceramic cup directly from the surface.

The water source for this research was a deep well. A 4-inch submersible pump was controlled by a pressure switch. A pressure tank was continuously pressurized and provided a low flow rate for the operation of individual trickle irrigation subsystems without frequent pump cycling.

Irrigation events were recorded with an event recorder and event counters on each controller. Hour meters were used to record total hours of irrigation for each controller. Cumulative flow meters recorded total volumes applied to each irrigation treatment.

Results and Discussion

The use of the automatic tensiometer controlled irrigation system resulted in several observations concerning the functioning and maintenance of the system. These are categorized as tensiometer service requirements, calibration requirements, and freeze protection requirements. Failures of the system, causes, and modifications required to remedy failures are also discussed.

Tensiometer service requirements

A tensiometer-controlled irrigation system requires periodic service for it to function properly. Service is required to purge air bubbles and control organic growths in tensiometers, and to verify that control system components are functioning under field conditions.

Purging air bubbles. Routine service normally consists of ensuring that the column of water is intact, and that air bubbles are purged from the instrument. This was accomplished by inspecting the tensiometers for air bubbles on a routine basis, opening the service cap, and refilling with water. Tensiometers that we used each had a reservoir for water storage built into the instrument. Thus, routine service consisted of opening (unscrewing) the cap and allowing air bubbles to escape and water to completely fill the column of the instrument.

We found that purging of air was required infrequently under the conditions of our study. Tensiometers were normally visually inspected every 2 weeks. Typically, no more than 3 or 4 of the 36 had air bubbles of a noticeable size. Air bubbles were mainly found in the –40 cb SWP treatment tensiometers. Few occurred in the –20 cb, and essentially none were found in the –10 cb treatment tensiometers. Air bubbles formed in the –40 cb tensiometers because more water exchange occurred as the soil experienced a greater degree of drying than in the wetter irrigation treatments. Also, more dissolved air was released from the water and collected in the tensiometers because of the lower SWP in the –40 cb treatments.

Even in the driest (–40 cb) treatment the problem of air entry was minor. It did not cause the tensiometers to fail to operate, and it was adequately handled by purging tensiometers as needed every 2 weeks. At 2-month intervals all tensiometers were serviced by uncapping them, purging them with a portable hand operated vacuum pump, and resealing them. This degree of service avoided problems with air bubbles in the instruments.

Deionized water, which was not boiled to remove air, was used in the tensiometers. This proved to be satisfactory for the high water potentials studied. At lower water potentials, boiling of the water may reduce problems with air accumulation by removing dissolved air from the water before it is used in the tensiometers.

Controlling organic growths. Organic growths in tensiometers lead to slowed response times due to clogging of the tiny pores in the ceramic cups. Clogging occurred as a result of the growth of slime on the surface of the ceramic. This problem was reduced by using deionized water in the tensiometers. With time, however, organic slimes still formed, due to the exchange of deionized water with the soil solution, or as a result of organic growths on the surface of the ceramic in contact with the soil.

With time, organic growths also occurred in the tensiometer water reservoirs and in that portion of the tensiometer tubes extending above the soil surface. An alga was observed to grow as a free-floating green mass and as a coating of the inside walls of the tensiometer tubes. This coating interfered with servicing of the tensiometers by blocking the view of air bubbles during visual inspection.

Surface organic growth problems were reduced by covering the tensiometers with cans to reduce the transmittal of sunlight. Relatively small cans (6 inch diameter x 8 inch depth) were used to cover the tensiometers including the protruding vacuum gauges. The cans covered only a small area of soil surface so that the soil under the cans could be wetted by rain or irrigation.

We found that tensiometers could not be used continuously in the field because of the progressive reduction in response that occurred due to organic slimes on the ceramic cup. After a period of several months, tensiometer responses slowed to the point that cleaning of the porous ceramic was required. This problem was more severe in those tensiometers located at greater depths in the soil profile. It was greatest at the 36 inch depth and much less severe at the 6 and 12 inch depths.

No quick method of cleaning was found to solve this problem. Sodium hypochlorite, hydrogen peroxide, and various acid solutions were used as cleaning agents, but none produced a rapid recovery of permeability. We solved this problem by completely drying the ceramic cups over a period of weeks or months. Our current practice is to exchange complete sets of tensiometers at least every 6 months. This drying period allows recovery of ceramic permeabilities, while not requiring frequent exchange of instrumentation in the field. A disadvantage is that it requires use of 2 separate sets of tensiometers. To facilitate exchange of tensiometers in the field, we constructed plugs on the tensiometer magnetic switches so that they may be plugged in for installation and unplugged for removal.

Field check of controller function. Because of the possibility of system failures, several techniques were developed to verify that the automatic control system was functioning properly. Extensive field data were collected on a 2-week schedule. At those times, the automatic control system was also checked. The functioning of the tensiometer magnetic switches was verified by moving the controller clock to the next scheduled irrigation period, then turning the magnetic switches to align them with the vacuum gauge needles, and observing that irrigation began. Treatments were allowed to irrigate for approximately 15 minutes while that portion of the irrigation system was inspected to assure that it was functioning properly. Cut or broken pipes, clogged emitters, or other nonfunctional components were located and repaired at this time.

Proper operation of the irrigation system was also checked by calculating flow rates for each period of automatic operation by dividing the flow volumes recorded on the flow meters by hours of operation recorded on the hour meters. Changes in flow rate from the long term average allowed problems with system clogging, broken pipes, etc. to be identified. Pressure gauges on each subunit were also used to help verify correct operation of the system.

Tensiometer calibration requirements

Magnetic switching tensiometers, like most other soil water instruments, require periodic calibration. Calibration was found to be required for both the vacuum gauges and the magnetic switches.

Calibration frequency. Frequent calibration was not found to be required. We found that factory calibration for the type of tensiometers that we used was very good. With time, however, the accuracy of the instruments was found to decline.

Calibration requirements depended on the SWP at which the tensiometers were set to operate. In general, a mechanical gauge such as the tensiometer vacuum gauge is more accurate near the mid-range of the gauge rather than near the extreme ends. We found the gauges to be least accurate when used for switching at the –10 cb level than at the other levels. At the –10 cb level, an error of 1 cb is relatively large (10%) in terms of soil water availability as compared to the –10 cb switching level. An error of 1 cb represents a much larger water content error at –10 cb than when the soil is drier at –20 cb or –40 cb. Thus, it is more important to accurately calibrate tensiometers at the low end of the scale than at greater tensions. Calibration at the upper end of the vacuum gauge scale was not a problem in our work because irrigations were all scheduled at SWP of –40 cb or less, which represented an allowable depletion of up to 80% of the available soil water for the Astatula fine sand studied.

We adopted a policy of calibrating instruments in the lab when they were removed from the field for control of organic growths. Typically, we recalibrated tensiometers just before they were installed in the field, and at least every 6 months.

A 6 month calibration schedule may be excessive for field scale agricultural systems, but calibrations at least annually are recommended for that purpose. Calibrations should also be performed if problems are suspected, such as gross over or under irrigation as compared to other nearby irrigation systems or accounting methods of irrigation scheduling.

Calibration equipment: A quick field check of a tensiometer vacuum gauge can be made with a test vacuum gauge on a hand vacuum pump. This equipment is available from the tensiometer manufacturers. This check, however, only tests the vacuum gauges and not the magnetic switches. It also typically tests the gauge on the "falling vacuum" portion of the test cycle. That is, gauge readings are checked after a large vacuum is imposed on the tensiometer gauge, and as vacuum is slowly bled-off and the gauge readings fall. This does not evaluate gauge accuracy on the "rising vacuum" portion of the test cycle which the gauge actually experiences under field conditions.

We constructed a tensiometer calibration facility to test and calibrate both vacuum gauges and magnetic switches. This facility used a vacuum chamber, a vacuum pump, and an accurate vacuum gauge to which the tensiometer gauges were calibrated.

Calibration was performed by servicing the tensiometer to be tested, inserting the ceramic cup into the vacuum chamber, starting the vacuum pump, and closing a valve which vents the vacuum chamber to the atmosphere. The vent valve was closed slowly until the SWP to be set was read on the test gauge. The tensiometer was allowed to equilibrate at this vacuum for several minutes, then the magnetic switch was slowly rotated until it lined up with the vacuum gauge pointer and switch closure occurred. This switch point was checked by releasing the vacuum in the chamber, then again slowly increasing it and verifying switch closure at the desired vacuum reading. The position of the magnetic switch was marked on the vacuum gauge with a permanent marker. This is the magnetic switch position that must be set when the tensiometer is installed in the field.

This calibration procedure has the advantage of testing and calibrating both the vacuum gauge and magnetic switch. It requires little specialized test equipment. The vacuum tank can be any small tank which will not collapse under atmospheric pressure with a vacuum inside. Tensiometers can be installed in a hole in the tank through a rubber stopper.

Freeze protection required

Tensiometers are subject to damage when exposed to freezing temperatures. Vacuum gauges will lose accuracy or be destroyed if water in the tensiometer freezes. Water in a tensiometer will normally not freeze until air temperatures fall several degrees below 32 F because the water is in close contact with warmer soil below the ground surface.

We used metal cans to cover tensiometers in the field. They have helped to protect against mild freezing temperatures. Since tensiometers were located under the tree canopies, they also benefitted from blanketing effects of the canopies. During this project our tensiometers have not been damaged by freezes. They were, however, uncapped, allowing the water to drain through the ceramic into the soil in anticipation of severe freezes.

Tensiometer control system failures

During the almost 3 years of this study, tensiometer failures occurred for several reasons. These were classified as: 1) air entry, 2) cavitation, 3) mechanical failures, 4) organic growths, 5) electronic failures, and 6) vandalism.

Air entry problems. Air entry results from improper sealing of tensiometers, leaks around fittings, and leaks through the ceramic cups. The incidence of tensiometer failures due to air entry has been extremely low in our work. On a few occasions, tensiometers were found empty of water because the cap was not properly sealed during servicing. In those cases, refilling, purging with a portable vacuum pump, and resealing aleviated the problem.

On no occasion did an air leak occur, either around a fitting, such as the point of attachment of the vacuum gauge, or around the ceramic cup. Also, on no occasion did an air leak through a ceramic cup cause failure of a tensiometer in the field.

Cavitation problems: Cavitation is the failure of the water column in a tensiometer to remain intact at low water potentials. This occurs when the soil around the tensiometer is allowed to become too dry. As the soil dries excessively, the vacuum gauge reading increases toward 100 cb, and water in the tensiometer vaporizes due to the low pressure. The vacuum gauge reading will normally be in the range of 80 to 90 cb when cavitation occurs.

In the first year of this project, problems with cavitation occurred in the driest (–40 cb) drip irrigation treatment. These resulted from inadequate water distribution in the area of the tensiometers. Because the –40 cb soil water potential is low, the soil surface became very dry before an irrigation was scheduled. When irrigated, the surface resisted wetting, and because of slope in the area of the emitters and tensiometers, runoff occurred. Water moved a short distance to a small depression where it collected, and infiltrated after the soil surface became wet. The runoff distance was sufficient to prevent lateral movement of water from rewetting the soil volume in the area of the tensiometers. Thus, these tensiometers dried to the point of cavitation. This problem was alieviated very simply: we dug small depressions (1-2 inches deep and about 6 inches in diameter) under the emitters near the tensiometers. The depressions collected water from the emitters located near the tensiometers, allowed the soil surface to become wet, and caused the irrigation water to infiltrate in the area of the tensiometers. Since this modification was made, the tensiometers have functioned satisfactorily in the dry SWP treatments.

The above solution to the problem of resistance of the soil surface to wetting could be used for field scale drip irrigation systems since few tensiometers are required to control relatively large irrigated areas. Thus, only a few locations would need to be monitored to assure that the soil is being irrigated in the area of the tensiometers. Also, if higher soil water potentials are used to schedule irrigations, resistance to wetting of the soil would be less because the soil would be wetter when irrigated. We did not observe the problem of resistance to wetting of the soil surface with the –20 and –10 cb treatments.

When tensiometers were located in the soil zone wetted by emitters, they functioned satisfactorily. When the soil zone was not rewetted by irrigation, water columns in the tensiometers cavitated, and the tensiometers failed.

Mechanical failures. These are failures of mechanical components due to external factors. These include damage from grove crews, animals, corrosion, solar radiation, or other factors.

Damage by grove crews: We commonly experienced damage to the automatic control system after harvest or other operations in which grove crews worked in the vicinity of the tensiometers or connecting wires. Once an electrical hookup wire was cut during grove operations. Burying as much of the control wires as possible is recommended for their protection. On several occasions hookup wires or magnetic switches were disconnected because someone tripped over the wire. Disconnecting a control wire interrupted the switching circuit, and prevented irrigations from occurring. Disconnecting a magnetic switch from its vacuum gauge caused the switch to close, and thus caused the irrigation system to operate the maximum number of hours per day set on the timer-controller.

Animals: We have not identified mechanical damage to the control system that could specifically be attributed to animals. We have, however, had occasional mechanical damage to trickle irrigation system components from animals chewing on pipes and emitters, primarily during drought periods.

Corrosion: On two occasions control circuits were interrupted by corrosion of connections. Those connections were made with wire nuts, and they corroded when exposed to water and fertilizer salts. Connections should be made waterproof to assure performance under field conditions. This will, however, cause difficulties when removing instruments for testing, repair or servicing. To facilitate servicing of connections, we built junction boxes for field connections to tensiometer magnetic switches using waterproof electrical service boxes. We used electrical plugs on the magnetic switch leads and installed sockets through the walls of the electrical service boxes. Tensiometers are now simply unplugged for service or replacement. This system has worked well under field conditions.

Exposure to solar radiation: Because tensiometer tubes are made of transparent plastic materials, some discoloration has occurred after long exposure to solar radiation under field conditions. This has been minimal because tensiometers were normally covered by cans and shaded by tree canopies in the field. Periodically we have had to replace the rubber stoppers which are used to seal tensiometer caps. The stoppers deterioriate after only three or four months depending on degree of exposure to solar radiation. These can be replaced by standard rubber stoppers, however, neoprene stoppers last much longer under field conditions.

Vacuum gauges on the tensiometers were sealed against moisture entry by the manufacturer. However, with age, leakage occurred on some gauges. Initially, leakage clouded the gauges, making them difficult to read. Shortly after moisture entry began, gauge accuracy deteriorated. Therefore, gauges were replaced when moisture condensation began to occur. We recommend replacement or repair of gauges as moisture entry begins to occur. This is believed to occur due to deterioration of sealant materials after prolonged exposure to field conditions.

Organic growth problems. Organic growths caused two problems with tensiometers: they discolored the water-filled transparent tubes, and (more seriously) they clogged the porous ceramic.

Green algal organic growths occurred in tensiometer tubes, primarily above the ground surface. These discolored the tubes, making it difficult to inspect them for air bubbles during servicing. This material was readily removed with a brush when tensiometers were periodically removed, cleaned, and calibrated.

Organic growths were maintained at low levels by using deionized water in tensiometers, thus avoiding adding nutrients. However, in normal operation, soil water enters the ceramic cups, contaminating the solution, and providing a medium for organic growths. Also, servicing of tensiometers under field conditions provides opportunity for contamination of the deionized water.

We did not use biocides to prevent growths in tensiometers. We used only the green dye provided with the tensiometers to color the solution and facilitate location of air bubbles during servicing. Organic growths might be eliminated by the use of a biocide, however, care should be taken to avoid a material that would inhibit root growth in the vicinity of the tensiometers.

On one occasion clean well water rather than deionized water was used to refill tensiometers. We rapidly experienced severe problems with discoloration of the tensiometer tubes due to iron (approximately 0.5 ppm) precipition and bacterial action. This problem was reduced by reverting to the use of deionized water.

We experienced a more serious problem with organic growths on the tensiometer ceramic cups. This problem occurred below the soil surface, especially on the deeper tensiometers. The problem was thought to be caused by bacterial slime that clogged the tiny pores in the ceramic cups. After several months in the field, tensiometer response was considerably slowed or completely stopped.

The ceramic clogging problem was solved by removing the tensiometers from the field and allowing them to completely dry to recover their permeability. Washings in chlorine and acid solutions were found to be ineffective in rapidly recovering tensiometer response times. We therefore purchased two sets of tensiometers: one set is dried for recovery of the ceramic permeability while the other is in use. This practice would significantly increase investments in instruments if practiced on a commercial scale, but it was the only way found to maintain the permeability of ceramic cups without using biocides.

Electronic component failures. Frequent power outages and power surges are typical of the region in which our work was conducted. Power outages were recorded in our data collection, and it was not unusual to experience at least one every two weeks during the summer rainy season. Both power outages and surges have caused relatively few problems with the automated irrigation system. The reason for this is believed to be because of the use of mechanical clocks and controller components. These machanical components are able to withstand some power surges without damage, and the fact that they were not operational during power outages was not a problem because the irrigation pump was also not functioning during that time. They simply restarted and continued any scheduled irrigation events after power was restored.

We have replaced only one mechanical clock on one of the six irrigation controllers used during the course of this study. We have had greater problems with our recording equipment, and we have replaced three hour meters and one event counter. We have also replaced one controller switch and one 24 VAC transformer. On one occasion, we experienced a lightening strike which burned out the surge protectors and the electric motor in our submersible pump and blew the 60 amp fuses in our electrical service box.

The problems with controller components were felt to be relatively miner considering the magnitude and number of power outages experienced at our field site. We have found the mechanical clocks and controller components to be very reliable for our field conditions.

Four of the 36 tensiometer magnetic switches have been replaced during the course of this work. These were thought to have failed because of accumulation of moisture or corrosion in them which caused the sensitive magnetic switching mechanism to fail. Users of this type of control system may expect magnetic switch failure to occur periodically under field conditions.

Vandalism. We experienced relatively few problems with vandalism at our field research site. Most commonly this resulted in damage to the irrigation system, such as cut pipes and missing emitters. On four occasions magnetic switches were removed from tensiometers, interrupting the automatic irrigation control system.

Irrigation control with tensiometers

The effectiveness of an automatic irrigation control system can be evaluated by comparing yields and irrigation requirements with and without the control system. Unfortunately, for the past 3 years of operation, severe freezes have prevented the harvest of yields representative of the citrus industry. Freezes have also caused loss of leaves and wood damage to trees, thus affecting water use. For this reason, yield results are not available, and irrigation requirements may not be representative of typical production systems. Thus, crop response to the control system is not presented in this paper.

Summary and Conclusions

From our experiences with the use of tensiometers to automatically control trickle irrigation of citrus under field conditions, we found that they can be used effectively to schedule irrigation applications based on soil water potential. To be functional, however, tensiometers must be located within the irrigated zone so that the soil will not dry excessively and cause them to fail. Tensiometers must also be located within the citrus root zone so that they can track the changes in soil water status as a result of water use.

Magnetic switching tensiometers were found to function well to initiate irrigation when a critical soil water potential was reached. However, to remain accurate over a long period of time, switching tensiometers required calibration of the vacuum gauges and magnetic switchs. Tensiometers needed regular maintenance, periodic inspection to assure that they were functioning, and protection from freezing temperatures.

To assure reliability, two or more tensiometers should be installed at each location instrumented, and they should be wired in parallel so that if one fails, the others will operate the irrigation system. Tensiometers should be used with timer-controllers because the time response of individual tensiometers is variable, and thus controllers should be used to apply predetermined amounts of water after irrigations are initiated by the tensiometers.

Over a 3-year period, the system was found to be a functional one which has the potential of saving water and energy. It was subject to failures due to mechanical damage, electrical problems, organic growths, vandalism, lack of calibration, and other causes. In conclusion, the system was not maintenance- and management-free. It required proper maintenance and periodic inspection to assure that it was functioning properly.

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