Irrigation Scheduling in Pecan Orchards using a Soil Water Balance Model

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Problem

Pecans (*Carya illinoinensis* (Wangenh.) K. Koch) are distributed over a wide area of geographic and climatic variation, extending from northern Illinois and southeastern Iowa to the coast of the Gulf of Mexico. Pecan trees require large amounts of water for their growth. The water use of pecan trees is greater than that of most row crops and it is estimated to be 40 to 51 inches per season for mature pecan trees growing in West Texas and New Mexico (Miyamoto, 1983). Flood irrigation is the oldest and most common irrigation system used in western pecan orchards and annual irrigation is about 80 inches (Miyamoto, 1983). Irrigation amounts and timing must be determined based on the ET requirements of the pecan trees to optimize growth and production (Stein et al., 1989; Miyamoto, 1985).

Most small- to mid-size pecan growers still base their irrigation schedule on intuition, or by counting the calendar days since the last rainfall or irrigation. Previous studies have shown that most well-managed pecan orchards receive much more water than what is really needed to optimize tree performance and productivity (Sammis and Herrera, 1999; Sorensen and Jones, 1999). As much as 10 feet of water per year have been applied in pecan orchards near Las Cruces, NM (Sorensen and Jones, 1999). Overirrigation not only leads to loss of water to deep drainage, but it also increases nitrate leaching into groundwater (Basso and Ritchie, 2005; Jones et al., 1999). Consequently, new strategies for irrigation of pecan orchards are now a necessity to reduce the volume of water used. Plant-soil-weather simulation models quantify soil water and soil nutrient processes and integrate knowledge from various disciplines to offer reasonable decision-making aids for evaluating probable outcomes and recommendations independent of location, season, crop, cultivar, and management. The number of costly, multi-treatment, multi-location, time-consuming field trails can be substantially reduced by combining field research with crop simulation models to quantify the magnitude and variability in response to various management strategies.

Objectives

The objective of the proposal was to introduce an alternative method for scheduling irrigation in pecan orchard through the use of the System Approach to Land Use Sustainability (SALUS) soil water balance model. The validation of the model in pecan orchards will allow for its use in other locations with different soil and climatic conditions.

Research method

The SALUS soil water balance model used in this study was initially developed by Ritchie et al. (1985), and further described in Ritchie (1998), Basso (2000), Basso et al. (2001) and Batchelor, Basso, & Paz (2002). The soil water balance model requires inputs for establishing how much water the soil holds by capillarity, how much drains out by gravity and how much is available for root uptake. The calculation procedures require knowledge of soil water contents (volumetric fraction) for the lower limit of plant water availability, for the limit where capillary forces are greater than gravity forces, and for field saturations. These variables can be estimated by soil texture using pedotransfer functions (Ritchie et al., 1999). The model has been tested for a wide range of soil and weather condition mostly on annual crops.

Data collection was conducted in the summer months of 2005 at the Texas A&M University Pecan Experimental Orchard (lat. 30°31'N, long. 96°24'W, elevation 220 feet), located near College Station, Texas. The size of the orchard is approximately 8.6 acres, and the soil type is a Westwood silt loam soil, 0 percent to 1 percent slope (fine-silty, mixed, thermic Fluventic Ustochrepts). The orchard was established in 1984 with trees at 35x35 feet spacing. The orchard is irrigated with microsprinklers. The experiment represents the first attempt to monitor soil water content in the orchard and to develop a system to schedule irrigation based on actual plant and soil needs.

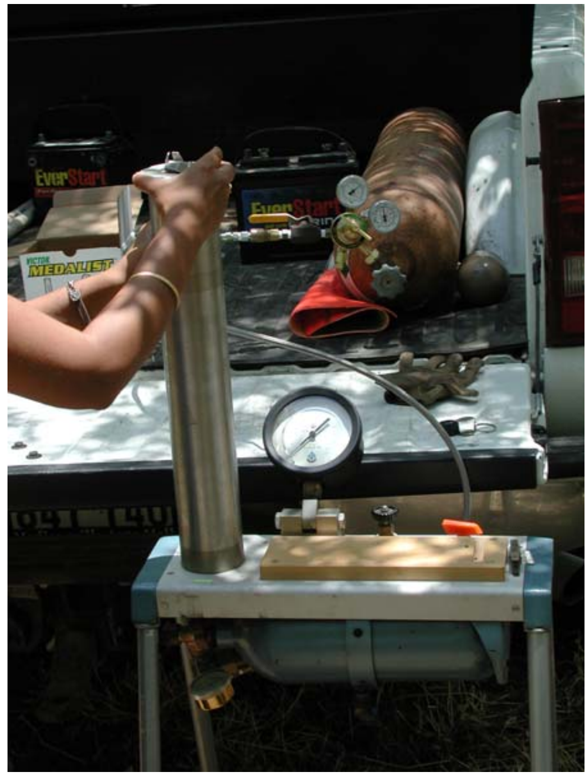
An automatic weather station (Campbell Scientific, Logan, Utah) was installed at the orchard and used to record solar radiation, wind speed and direction, air temperature and relative humidity, precipitation. Weather data were collected every minute, and recorded as 15-minute averages.

Nine ‘Pawnee’ pecan trees were selected for uniformity of height, canopy width, and trunk diameter. On July 21, 2005, the crop load of the test trees was adjusted by thinning overbearing test trees using a mechanical shaker. The reduction of the 2005 crop load allowed for better late-season carbohydrate accumulation and will potentially increase blooming and yield in the 2006 growing season.

A soil coring truck with a hydraulic press and auger attachments was used to extract soil cores for bulk density, particle density, particle size analysis, and tube installation. The vertical holes drilled with the auger were roughly 1.75 inches in diameter. Four PVC tubes (i.d. = 1.5 inches; length = 10 feet) where then placed on the north, south, east and west sides at 6 feet distance from the trunk of one tree.

Soil water content was measured using a neutron probe (Model 3321, Troxler Electronic Laboratories, Inc., Research Triangle Park, N.C.). Predawn and midday leaf water potential (ψ) was measured using a Scholander-type pressure chamber (Soil Moisture Equipment Corp., Santa Barbara, Calif.). Predawn ψ was measured between 4 a.m. to 5 a.m.(Central Time), while midday ψ was collected between 12 p.m. and 2 p.m. according to the procedure described by McCutchan and Shackel (1992). Predawn ψ was measured on Sept. 5, 2005. The orchard was then irrigated for 48 hours and ψ was measured again on the morning of Sept. 9, 2005.

PVC pipes were installed using the soil coring truck to facilitate the use of neutron probes to monitor water conditions.



Pressure chambers were utilized to measure predawn and midday water potential of pecan leaves.

After 48 hours of whole block irrigation, the soil profile was wetted to a minimum 18" depth on the north, south, and west sides of the trees. Irrigation riser placement on the west side of the trunk does not allow for complete coverage of the east side of the tree's soil, due to trunk shadowing. The average leaf water potential of the north and south side of the test trees measured before the irrigation was -0.25 MPa and -0.27 MPa, respectively. After the irrigation, the average predawn leaf water potential of the north and south side of the tree canopy was -0.22 MPa and -0.23 MPa, respectively.

Results

Preliminary data collected in 2005 have allowed us to become familiar with the technology that will be utilized in 2006. Setting up an experiment which involves the use of a delicate and somewhat hazardous instrument such the neutron probe requires extensive training and paperwork on behalf of the operators. General radiation safety training, field training and transportation training for the neutron moisture probe have now been completed by Mr. Byron Whisnant (a M.S. student involved in the project) to allow full use and mobility of the moisture probe. Mr. Whisnant has also become very familiar with the installation of the access tubes in the ground, a lengthy process that is still underway. When completed, a total of 18 tubes will be in place, with two tubes per tree and two additional tubes will be placed outside the tree influence. Mr. Whisnant has also been working on building a set of "calibrating barrels" to use when neutron probe measurements will be performed. This "saturated and air dry barrel" system allow us to calculate the slope of the calibration curve more precisely and thus to minimize the error in calculating soil water content.

Future Studies

The information gathered so far is not sufficient to make particular conclusions until it is integrated with the data that will be collected in 2006. Now that the preliminary data have been gathered, the instruments have been calibrated and utilized several times, and the installation of access tubes is almost complete. Our plan for 2006 is to apply three different irrigation regimes and monitor soil water content and plant physiology parameters for the entire season. The three treatments will include trees that will receive water only from natural precipitation (rain-fed treatment), trees that will be irrigated at regular intervals (a traditional treatment that is still common among growers), and trees that will receive water based on soil water content readings (conservation treatment).

This proposal herein seeks to accomplish, through the model validation procedure of soil water content measurements, a correct estimate of the soil water available for pecan trees, thus minimizing water losses and environmental impact. Research results will consist of soil water content measurements at different depth in the soil profile. Simulated soil water content data will be shown and compared with measured data. Soil water content data will then be correlated with tree size, leaf area index, leaf transpiration rate and leaf water use efficiency to further validate the model prediction for irrigation scheduling.

Deliverables and Outcomes

Pecan cultivation is a type of horticultural operation that can be maintained *only* with enormous volumes of water, which is extremely precious in regions where natural rainfall and supplemental irrigation are limiting. Reducing water inputs is vital for the future of the pecan industry.

With the results of the present study, we intend to obtain more information on how to optimize crop water use and quantify the variability of soil water content in commercial pecan orchards. The overall goal is to better estimate processes that account for water availability and water use in pecan orchards, thus leading to best management practices for water conservation.

The enhancement and optimization of water productivity (in measures of production or economic savings per units of water transpired) require accurate knowledge on the dynamics of crop growth and productivity responses to water stress. Such knowledge can be provided and improved with the use of such simulation models as SALUS. This is particularly important for areas where rainfall is limited and irrigation water supply is declining and/or is unreliable. Previous studies have shown that the use of SALUS to precisely apply irrigations based on crop and soil water needs reduced the volume of irrigation by roughly 30 percent. Perhaps similar water savings could be achieved by using SALUS in pecan orchards, but this will need to be verified by field research.

The application of the SALUS model will provide a better tool for an integrated plant water productivity assessment and enhancement across such domains as production and farming systems. SALUS can help decision makers in determining where and how effective savings in water use and consumption can be made, as well as where and how the highest productivity gains can be achieved by redirecting saved water resources.

Final results will be presented at industry and Extension meetings (e.g., Texas Pecan Growers Association, Western Pecan Growers Association, field days, etc.), and published in industry publications (e.g., *Pecan South*) and in scientific journals (e.g., *HortTechnology, Agriculture, Ecosystems and Environment, etc.*).

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