Sub project title: Model of water and nitrogen management in Pecan trees under normal and resource-limited conditions.

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PROJECT TITLE: **Advanced sensing and management technologies to optimize resource management in specialty crops – case studies of water and nitrogen management in deciduous crops under normal and resource-limited conditions**

1.0 PROJECT DESCRIPTION

1.1 **Introduction**

Nut production from pecans, almonds, and pistachios figures heavily in the economies of California, Texas, and New Mexico, and several other states. Production depends upon irrigation, but water supplies for irrigation in the near term appears likely to be cut severely in California (15-50% of normal) and surface irrigation water supplies have been reduced in low runoff years in New Mexico. Only the supplication of the surface water with ground water has allowed the pecan growers to apply full irrigation amounts to the pecan trees. In the long term, both climate change and relentless population growth and associated diversion of water to municipal and industrial growth will reduce irrigation water supplies permanently.

Crop modeling in general is a major research tool in horticulture (Gary et al., 1998), with simulation models being used to understand the integration of physiological processes and mechanisms of tree response to stress. Tree growth models usually include four main carbon processes: photosynthesis, respiration, reserve dynamics, and carbon allocation (LeRoux et al., 2001). In forestry, over 27 tree growth models have been developed, each with the main carbon metabolism processes described but each having a different representation of these processes—from empirical relationships to mechanistic models of instantaneous leaf photosynthesis—to account for the major environmental variables. These same processes and deficiencies occur in the smaller number of developed fruit and nut tree models. Fruit and nut tree models have been developed for pecans (Andales et al., 2006), apples (Seem et al., 1986), peaches (two models: Lescourret et al., 1998; Allen et al., 2005.), and avocados (Whiley et al., 1988)

Because fruit and nut tree models are built to be used to manage orchards to maximize fruit or nuts and not growth, they must contain pruning sub models. Figure 1 from Andales et al. (2006) shows a flow chart for the pecan growth tree growth submodel showing the allocation of pecan growth, yield, and alternate bearing (Andales et al., 2006).

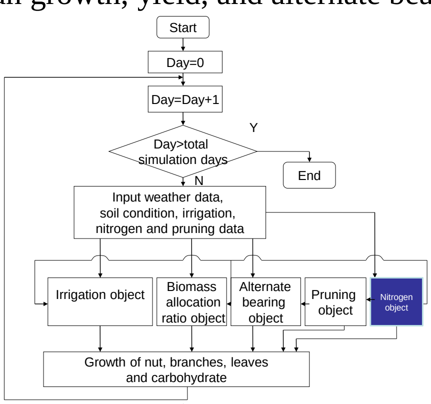

Figure 1. Flow chart of the growth object.

If a tree growth model is built as a user-friendly decision support system, it should include all objects necessary to simulate crop growth using either mechanistic or empirical functional relationships (Reynolds & Acock, 1997 A programming approach is to develop object-oriented decision support models that contain real-world objects with software counterparts. Each object consists of encapsulated data (attributes) and methods (behavior and interactions). Objects interact with each other and with their environment. Objects also provide interfaces by which users can change attributes or execute methods.

With the discussion of the limitation of nut tree model in mind the overall goal of the research was to development an improved management model to monitor and predict nutrient demand and nutrient status in pecan trees along with the interaction of nutrient and water stress on nut yield. Specifically the objective was to develop an optimal schedule (timing and amounts) of irrigation and N fertilization that maximize yield when irrigation water is cut to 50% (or other specified fraction) of normal and the nitrogen application efficiency is increased from 50% to 80% by using a complex photosynthesis pecan tree model to develop the nitrogen and water use efficiency functions need by the simpler pecan grow model.

1.2 **Methods**

If trees or other plants are given reduced and water supplies, many physiological acclimations occur with the first response of the tree to be a reduction in stomatal conductance, g_s. This cuts leaf transpiration almost in proportion - not quite as much, because leaf cooling is reduced, and the rise in temperature raises the leaf-to-air gradient in water-vapor pressure. The reduction in g_s also cuts leaf photosynthesis, but considerably less than proportionally - the stomatal resistance (inverse of conductance) is a much smaller part of the total pathway resistance for incoming CO_2. Consequently, water-use efficiency (WUE), as the ratio of photosynthetic rate to transpiration rate, rises.

Measurements of water use efficiency under non water stress conditions have been previously be made (Wang et al. 2007) to verify both the complex photosynthesis model and the simple pecan plant grow model. The complex photosynthesis model was calibrated again two dry down irrigation cycles imposed on a pecan orchard near Las Cruces, NM to verify the model under moisture stress conditions and against selected pecan trees in the same orchard showing nitrogen and water stress conditions. The complex photosynthesis model was then run under moistures and nitrogen stress conditions to develop the WUE function vs plant water potential and leaf nitrogen level used in the whole pecan plant model. The nitrogen stress function was incorporated into thee pecan plant model that was then tested against a separate water nitrogen stress experiment in another climate environment in Oklahoma (Smith et al 1985) and Tx (Rohla et al 2007). The pecan trees at the Oklahoma study site only received rainfall and nitrogen amounts from 0 to 265 kg/ha. The climate data was acquired from NCDC for Stillwater Oklahoma 16 km north of Perkins Oklahoma where the study was conducted. The Texas study was a Charlie Tx and the climate data came from NCDC Hermerata Tx . The pecan trees were not stressed for nitrogen or water but both the Tx and Ok orchards were stressed for potassium and a linear potassium stress function was added to the model.

1.3 Initial Results

The photosynthesis pecan model's relative change in transpiration occurs linearly as leaf N decreases expressed as a relative value of the 2.6% nitrogen starting point (Nr) under water stress condition when transpiration was 50% of transpiration non-stressed (Figure 2) equation 1. Modeled WUE also decrease linearly with a decrease in relative N because the leaf temperature rises when Photosynthesis capacity is lowered due to nitrogen stress conditions in the leaves (equation 2). When water is not limiting a decrease in transpiration caused only by nitrogen stress also caused leaf temperature to rise by 3C from the max. N level to lowest N level and causes a decrease in WUE and relative E(Er). The decrease in WUE as minimal and was not incorporated into the Pecan grow model. The measured relative decrease in growth related linearly to relative transpiration from the experiment by Sparks and Baker (1975) agrees with the model simulation of pecans under both nitrogen and water stress until the nitrogen level becomes less 1.66% nitrogen at which time the relative transpiration decreases as a non linear function. (Figure 2).

Er = 0.7134 Nr + 0.326 (1)
Coefficient of determination = 0.9865

WUE = 0.4059Nr + 0.6015 (2)
The coefficient of determination = 0.9971

Consequently, the interaction between nitrogen stress and water stress on evapotranspiration in the pecan growth model is multiplicative Eq 3

Et= Etns* soil water stress function* nitrogen stress function. (3)

The nitrogen stress function is from equation 1 and the water stress function is:
Et/Etns= 0.5RAW (4)
Where: RAW is relative available water.

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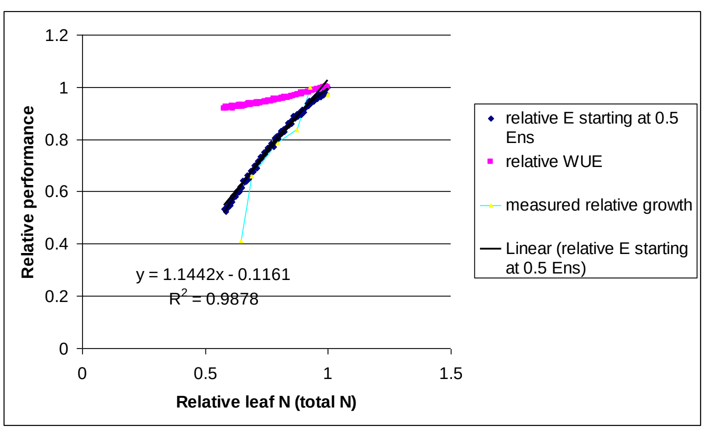

Figure 2. Modeled relative N of total N (0.3% is the structural part of leaf N) vs relative

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The Pecan model has been verified against experiments reported in the literature conducted in Oklahoma and Texas. Figure 1 compares the measure and modeled pecan yield for an experiment conducted at Charlie Texas. The experimental trees were not stressed for nitrogen and water but were stressed for potassium and the model now include a potassium stress function that reduces ET and yield due to limiting potassium availability in the leaves.

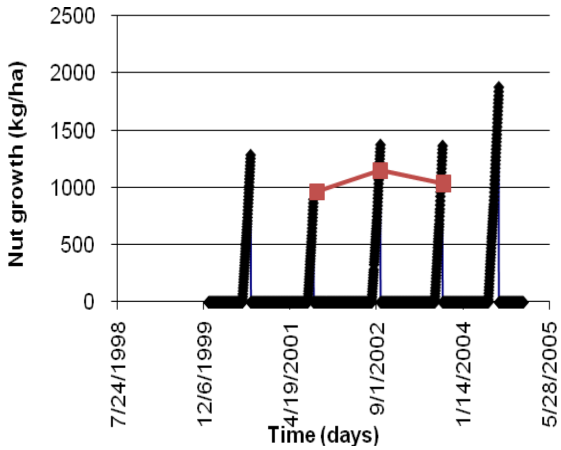

Figure 1 Measured and model pecan yield for an experiment at Charlie Texas reported by Rohla et al 2007.

Figure 2 presents the results of modeled and measured pecan yield in an Oklahoma experiment where no irrigation or nitrogen was applied to the orchard showing the problem of alternating bearing on yield when trying to compare the first years simulation to measured data. It is necessary in a pecan orchard to start the model simulation several years prio to the measurenments inorder to have a correct simulation comparion between modeled and measured yield data where the affect of alternate bearing can be observed in the orchard. The model runs for Oklahoma also include the reduction in yield due to Potassium stress.

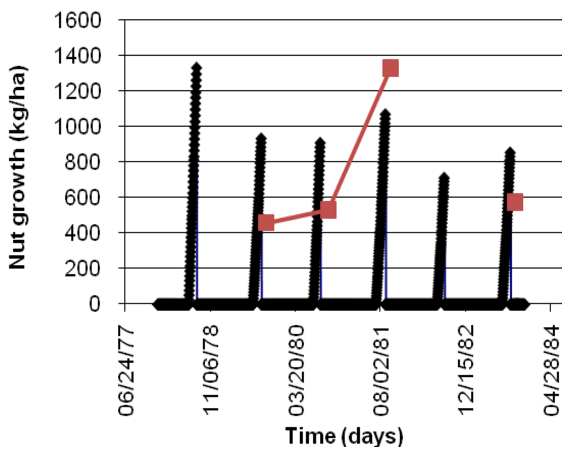

Figure 2 Measured and model pecan yield for an experiment reported by Smith et al 1985 in Ok when no fertilizer was applied.

2.0 **OUTPUTS**

2.1 Activities: Developed a web out reach page (http://hydrology1.nmsu.edu/nm-soil-water-model/Pecan-model-mainpage.htm) for presentation of the model.

3.0 OUTCOMES / IMPACTS: The model development has demonstrated the sensitivity of pecan yield to water, nitrogen and potassium stress levels and shows how when water is limiting growth, then nitrogen application should be decrease to match the nitrogen requirement of the limited growth pecan trees.

4.0 **PUBLICATIONS** : Sammis, T. W., Vince P. Gutschick, Junming Wang, Manoj K. Shukla, and Rolston St. Hilaire. Modeling pecan growth and fertilization under nitrogen and water stress. Presented at the 2009 Irrigation Show, Innovations in Irrigation Conference, December 2-4 in Henry B. Gonzalez Convention Center, San Antonio, TX

5.0 **PARTICIPANTS**

A graduate student in Plant and Environmental Science received instruction on modeling nitrogen uptake using an excel based plant grow model.

6.0 **TARGET AUDIENCES**

The target audience is pecan growers and farm consultants with the intention of showing them that all inputs must be match so that excess nitrogen should not be applied when water is limiting production.

6.2 **Efforts** : The researchers will present results to the New Mexico Pecan growers association.